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COMPARATIVE CHARACTERISTICS OF UNITED STATES COAST
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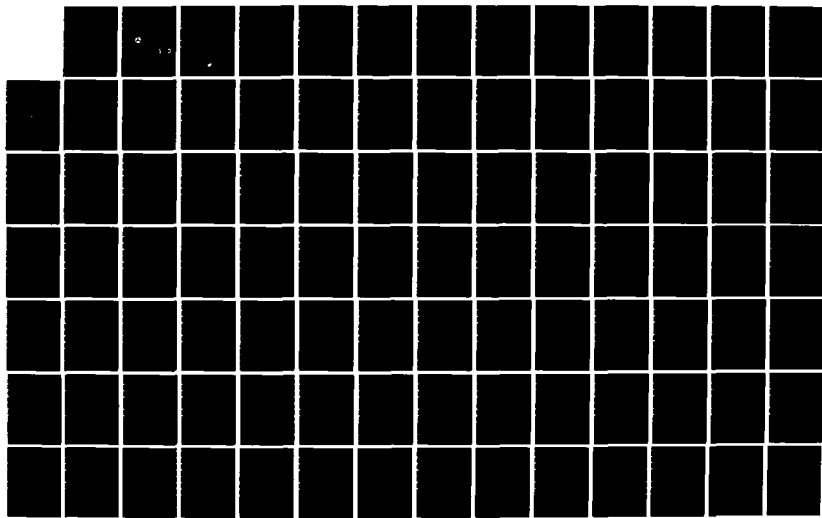
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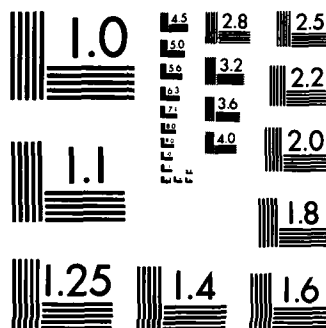
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Report No. CG-D-21-85

COMPARATIVE CHARACTERISTICS OF
UNITED STATES COAST GUARD
95' AND 82' CLASS PATROL BOATS (WPB)

AD-A157 552

Thomas J. Coe
and
Ryan R. Young



FINAL REPORT
APRIL 1985

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Prepared for:

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16. Abstract The performance characteristics of the Coast Guard 95' and 82' WPB class patrol vessels are documented and compared. Ship motions in waves, maneuvering capability, tactical data, noise levels, fuel consumption, and shaft horsepower were measured and analyzed. Seakeeping performance was measured during a side-by-side test of the CGC CAPE FAIRWEATHER and CGC POINT KNOLL in 3-foot significant waves.					
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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	* 2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in ²	square inches	6.5	square centimeters	cm ²
ft ²	square feet	0.09	square meters	m ²
yd ²	square yards	0.8	square meters	m ²
mi ²	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (WEIGHT)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft ³	cubic feet	0.03	cubic meters	m ³
yd ³	cubic yards	0.76	cubic meters	m ³
TEMPERATURE (EXACT)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in = 2.54 (exactly) For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price \$2.25. SD Catalog No. C13.10.286

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm ²	square centimeters	0.16	square inches	in ²
m ²	square meters	1.2	square yards	yd ²
km ²	square kilometers	0.4	square miles	mi ²
ha	hectares (10,000 m ²)	2.5	acres	
MASS (WEIGHT)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m ³	cubic meters	35	cubic feet	ft ³
m ³	cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (EXACT)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

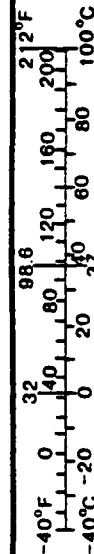


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1.0 INTRODUCTION

The United States Coast Guard Office of Research and Development is in the process of evaluating advanced surface craft concepts as well as documenting the performance of its present Patrol Boat Classes (WPB) to support the acquisition process. The Coast Guard Research and Development Center has been directed under the Advanced Marine Vehicle (AMV) Project's 9207.2 Ship Test and Demonstration element to collect baseline data on both the 95' and 82' WPB's.

This data will be incorporated into the AMV data base to support the WPB vessel acquisition in two ways. First, the baseline performance data can be used directly by Headquarters personnel when evaluating proposed replacement craft. Next, the R&D Center will utilize the data as input for various operations analysis computer models which evaluate a vessel's ability to perform Coast Guard missions. Proposed replacement craft can then be evaluated and compared to our present WPB 82' and 95' vessel capabilities.

2.0 DESCRIPTION OF THE VESSELS

The United States Coast Guard patrol craft (WPB) fleet consists of 25 "CAPE" class 95 feet long and 53 "POINT" class 82 feet long. Both classes are conventional displacement hull designs. There are three series in each class as described in Tables I and II.

3.0 TESTS AND DATA COLLECTION

The objective of this technical evaluation is to quantify the calm water and seakeeping performance of the Coast Guard 95' and 82' patrol craft. Calm water performance tests included speed vs. power and fuel consumption, zig-zag, spiral, tactical data runs, and a noise level survey. Seakeeping tests included ship motion in waves and susceptibility to slamming on the CGC CAPE HIGGON and a side-by-side ships motions comparison of the CGC POINT KNOLL and CGC CAPE FAIRWEATHER. The execution details of these tests can be obtained by referring to the GENERAL TEST PLAN FOR MARINE VEHICLE TESTING, reference (1).

This data was collected during two separate tests. The CGC CAPE HIGGON, a 95' WPB, was tested in January 1983 off Gloucester, Massachusetts, to obtain baseline seakeeping and calm water performance data. The CAPE HIGGON was instrumented for calm water performance because as an "R" series vessel, rebuilt with new main engines, electronic and habitability improvements, it represents the majority of 95' WPB's. The side-by-side motion in wave test conducted off New London, Connecticut, in August 1983 with the CGC CAPE FAIRWEATHER, a "B" series 95' WPB, and the CGC POINT KNOLL, a "C" series POINT class 82' WPB, documented comparable seakeeping abilities of both craft. Calm water performance data was collected on the CGC POINT KNOLL during this second test period.

Two identical ship motion packages placed at the ships' center of gravity were used to document roll, pitch, and heave response of the vessels during side-by-side seakeeping tests as well as yaw rate and yaw angle during spiral

TABLE I

95' WPB - PRINCIPAL CHARACTERISTICS







Length Overall	95'-0"
Length Between Perpendiculars	90'-0"
Beam, Molded at Deck Amidships	19'-10"
Depth, Molded Amidships	10'-8 1/2"
Draft, Mean to Design Waterline	4'-6 1/2"
Hull	Steel
Superstructure	Aluminum
Framing	Longitudinal

	NOT TESTED "A" Class	USCGC CAPE FAIRWEATHER "B" Class	USCGC CAPE HIGGON "R" Class
Displ, Full Load, LT	102.7	105.0	103.5
Displ, Light Ship, LT	79.6	82.5	93
Complement	15	15	15
Provisions for	14 days	14 days	14 days
Fresh Water Capacity, gal	1340	1340	1340
Diesel Oil Capacity, gal	3145	3145	3145
Maximum Speed, knots	19.8	19.5	24
Cruising Range at 10 kn	2154 nm	2307 nm	2300 nm
Propellers	Two-48" dia, 5 blades	Same as "A"	Same as "A"
Shaft Horsepower, total	2200	2200	3000
Main Engines	Four-VT12-M Cummins	Same as "A"	Two-GM 16V 149TI
Generators	Two-20KW	Same as "A"	Two 30 kw
At Full Load Condition:			
KG	7.10'	7.44'	7.12'
GM	4.75'	4.30'	4.64'
LCG	5.05' aft Σ	5.72' aft Σ	4.55' aft Σ
LCB	4.94' aft Σ	5.00' aft Σ	4.96' aft Σ
Moment To Trim 1"	20.46 ft-tons	20.47 ft-tons	20.48 ft-tons

TABLE II

82' WPB - PRINCIPAL CHARACTERISTICS

Length Overall	82'10"
Length Between Perpendiculars	78'0"
Beam, Molded at deck (Over Guards)	17'7"
Depth, Molded, Amidships (Raised Deck to Keel)	12'0-1/8"
Draft, Mean to Design Waterline	4'8-3/4"
Hull	Steel
Superstructure	Aluminum
Framing	Longitudinal

	NOT TESTED "A" Class	USCGC POINT KNOLL "C" Class	NOT TESTED "D" Class
Displ, Full Load, LT	67.5	66.1	69.4
Displ, Light Ship, LT	52.1	51.8	56.5
Complement	8	8	8
Provisions for	10 days	10 days	10 days
Fresh Water 100%, Gal.	1554	1271	1271
**Diesel Oil, 95%, Gal.	1830*	1830*	1830
Maximum Speed, Knots	23.5*	23.7*	22.6
Max. Sustained (633 rpm)			
Cruising Speed	18.2*	18.5*	18.5
Econ. Cruising Speed, knots	8.0*	8.0*	8.8
Max. Cruising Distance	1577*	1584*	1584
Propellers	Two-42"dia-44"pitch 5 blades*	Same as "A" Class	Same as "A" Class
Shaft Horsepower	1600*	Same as "A" Class	Same as "A" Class
Main Engines	2 Cummins Diesels	Same as "A" Class	Same as "A" Class
Generators	Two - 20 KW	Same as "A" Class	Same as "A" Class
Armament	81 mm mortar-50 cal	Same as "A" Class	Same as "A" Class
At Full Load Condition			
KG***	8.61'	8.69'	8.55'
Corrected GM	3.13'	3.15'	3.07
LCG	4.24' aft 	4.28' aft 	4.92' aft 
LCB	3.83' aft 	3.78' aft 	3.90' aft 
Moment to trim 1"	11.1 ft-tons	11.05 ft-tons	11.12 ft-tons

Notes: (*) Revised February 1971

(**) Usable fuel only. Usable fuel is defined as the gallonage that can be pumped from the port and starboard tanks with low suction piping. Centerline tank is considered emergency fuel.

(***) Baseline is 1.02' below keel (skeg) at midships for this condition.

and zig-zag maneuvers in calm water. Statistical shock recorders were used for recording slams above 1 g encountered by the CAPE HIGGON in 4-5 foot head seas. Susceptibility to slamming tests were not conducted on the POINT KNOLL because an adequate sea state of 4-5 feet was not available during the test period.

Shaft torque, horsepower, and rpm were measured with two identical Acurex model 1202A horsepower meters. A full bridge strain gauge was applied to the shafts to measure torque. An FM telemetry system powered and retrieved the strain gauge signal.

Data during all tests was collected by a 14-channel Racal Store 14D analog tape recorder. During the testing of the POINT KNOLL, a new computerized Hewlett-Packard data acquisition system was installed in addition to the analog tape recorder. With that system installed, all sensor signals could be digitized and analyzed on board to ensure good data quality and provide instant checking and verification of ship test results. The location of all sensors utilized during the tests on the 82' and 95' WPB's are shown in Figures 1 and 2, respectively. A detailed description of ship test equipment is provided in Appendix A.

Ship position information necessary for determination of turning circle diameters, advance, transfer, crash stop, and fast start distances was obtained utilizing a Motorola Mini-Range system deployed around Block Island Sound. Ships heading, rudder angle, and start and stop times were recorded on analog tape aboard the vessel synchronized by the use of a time code generator with the Mini-Range receiver system located on Fishers Island.

4.0 DATA ANALYSIS

Ship motion and wave height data was analyzed and averaged over 20 to 30-minute records for each of 5 legs of the seakeeping runs. The average highest one-third ($H\ 1/3$) and average highest one-tenth ($H\ 1/10$) amplitudes were computed utilizing two computer programs titled GENSES and GENPEAK.

The GENSES program runs on a Hewlett-Packard (HP) 9835B computer. It digitizes up to 20 channels of analog data recorded on the Racal tape recorder(s) with the use of an HP data acquisition control unit and HP digital volt meter.

After GENSES is executed, the GENPEAK program is utilized to search the digital file for peaks, record all peaks exceeding a defined limit (i.e. 1 foot wave height), and then sort all peaks from high to low. Subsequently, the $H\ 1/10$ and $H\ 1/3$ values are averaged.

Selected motions are further analyzed in the frequency domain. Response Amplitude Operators (RAO's) are calculated for heave and pitch motions during head seas, and roll RAO during beam sea side-by-side runs. The heave RAO for CAPE FAIRWEATHER could not be calculated due to equipment failure, resulting in no heave data for that vessel. Calm water and seakeeping performance data tables are included in Appendices B and C respectively. Details of the RAO analysis and data plots are provided in Appendix D.

The diagram shows the upper deck layout from bow to stern:

- LAZARETTE**: Located at the bow.
- HOLD**: Adjacent to the lazarette.
- MACHINERY**: Contains engine and pump symbols.
- GALLEY P.O.**: Includes a sink and stove symbol.
- C.P.O. STATEROOM**: Officer's quarters.
- BRIDGE**: Navigation station.
- CREW BERTHING**: Crew sleeping quarters.
- FORE PEAK**: Forward-most section.

Dimensions along the right side (from bow to stern):

- 70.17'
- 60.58'
- 38.5'36"
- 20'
- 6'
- FP (Fore Peak)

SCALE 3/32" = 1' 0"

Center of Gravity (KG 8.69' above baseline, LCG 4.28' aft midships)

Ship Motion Package

Shaft Horsepower Meter

Vertical Accelerometer

Data Acquisition System

FIGURE 1. - 82' WPB Sensor Locations

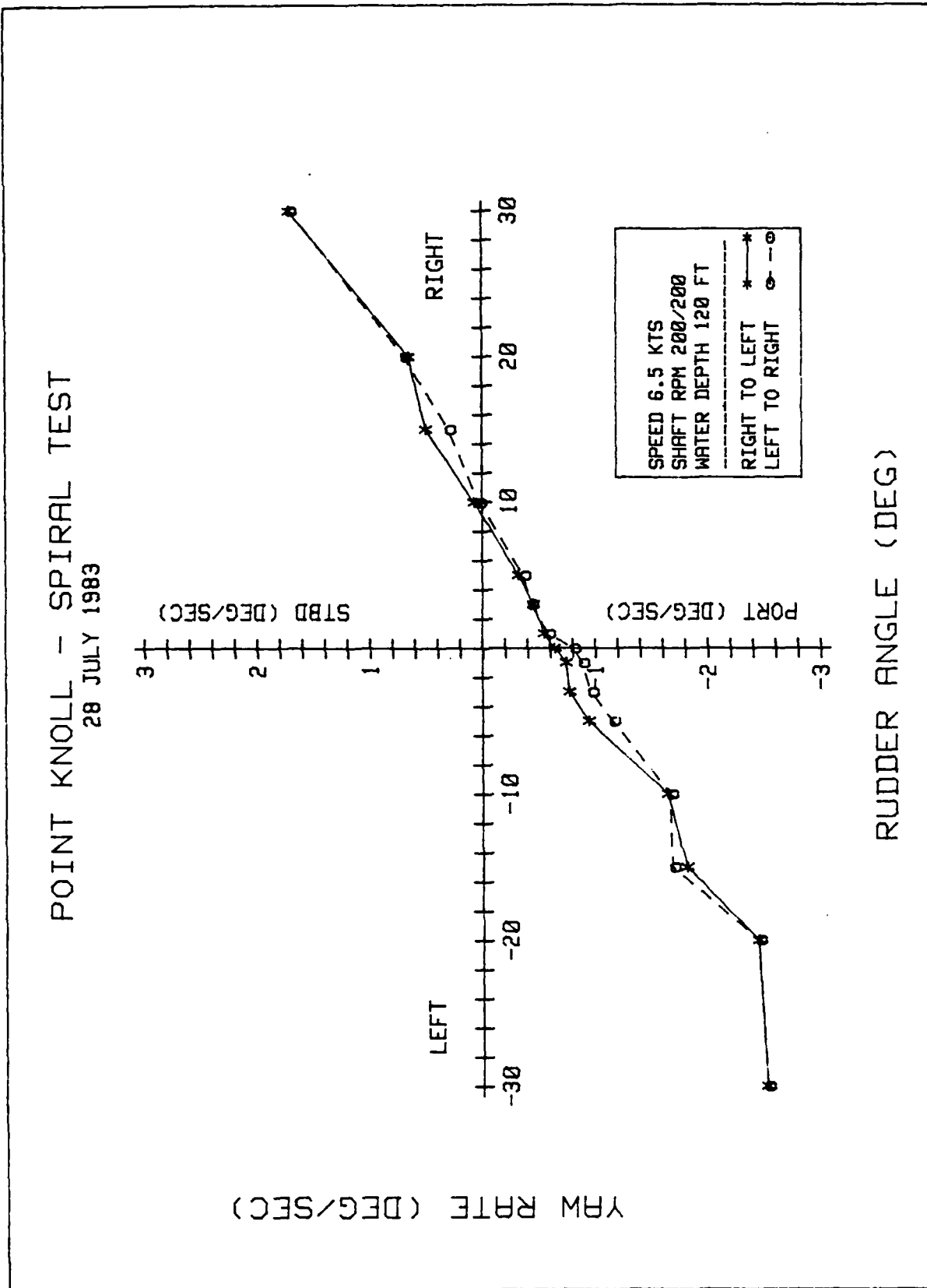


FIGURE 13 - POINT KNOLL - SPIRAL PLOT - 6.5 KNOTS

potentiometer installed was calibrated using the auxiliary steering tiller in place on the rudder post. The 4 degrees right rudder at 16.5 knots and 9 degrees right rudder at 6.5 knots necessary to obtain 0 yaw rate indicates that the 0 rudder angle was most likely calibrated a few degrees to the left of center. Both vessels demonstrated good course keeping stability at low rudder angles as seen in Figures 13 to 16. Tabular data is presented in Appendix B, Tables B-IV and B-V.

Zig-zag (overshoot) maneuvers were also conducted. These tests documented the ability the ship's rudder system has in controlling the vessel. Overshoot yaw angle is an indication of the amount of anticipation required of a helmsman while operating in restricted waters. The time required for the ship to react to a 20 degree rudder change is an indication of rudder effectiveness at that speed. Zig-zag plots for the CAPE FAIRWEATHER are presented in Figures 17 to 19 and the tabular data is included in Table B-VI in Appendix B. Note that the overshoot angle tabulated is the average of all the executions recorded during each maneuver. The zig-zag test for the POINT KNOLL was unsatisfactory, and the test will be redone when a "POINT" class cutter is re-tested for fuel consumption.

5.4 Noise Levels

The OSHA Standard for noise levels is presented in Figure 20. Noise level surveys conducted on both classes are presented in Tables B-VII and B-VIII in Appendix B. The CGC CAPE HIGGON had very loud noise levels which quickly surpassed ISO standards as seen in Figure 21. The CGC POINT KNOLL was much quieter as seen in Figure 22.

5.5 Towing

The POINT KNOLL towed the CAPE FAIRWEATHER at various speeds in order to measure the towing capability of the 82' WPB and document the drag of the 95' WPB. The results of this data, obtained with the CAPE FAIRWEATHER's propellers freewheeling, are presented in Figure 23. Time did not permit a reversal of the towing situation.

6.0 SEAKEEPING PERFORMANCE

6.1 Sea State Information

Wave height information was obtained using a Wave Rider and a Endeco 956 Wave-Track directional buoy during the side-by-side ship test. A comparison of significant wave heights measured from both buoys is presented in Figure 24 and Table B-IX. The Endeco buoy consistently gave slightly lower significant wave heights during the side-by-side seakeeping runs on 2 August 1983. The average of all significant wave height runs shown in Figure 24 is 3.0 feet. The sea state was fairly unidirectional as seen in the directional wave energy plot obtained from the Endeco buoy, Figure 25. Visual estimates placed the major swell coming from 170°T, the same as the Endeco buoy. This course was used as the head sea condition. Wind driven waves were developing from 145°T; however, this is not clearly seen on the directional plot. Probably the wind waves were at a slightly shorter period than the software's 3.3 second cut-off (0.30 HZ). A three dimensional view of relative wave energy from the Endeco data is presented in Figure 26.

$$\frac{315}{TIC} = 98$$

METERS BETWEEN TICS X & Y AXIS = 98

000183 CAPE FAIRWEATHER 0 KTS 10 DEG RIGHT

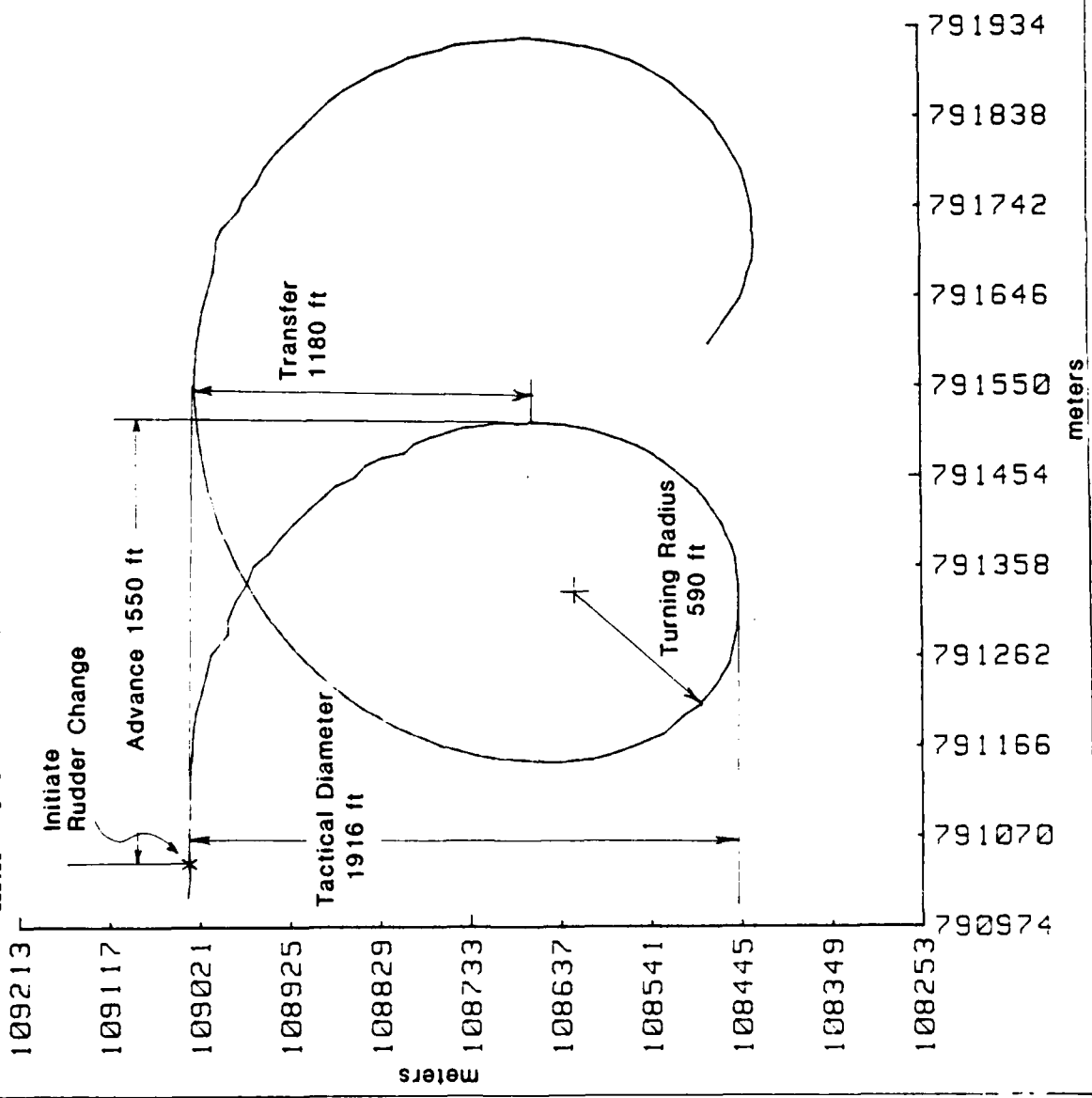
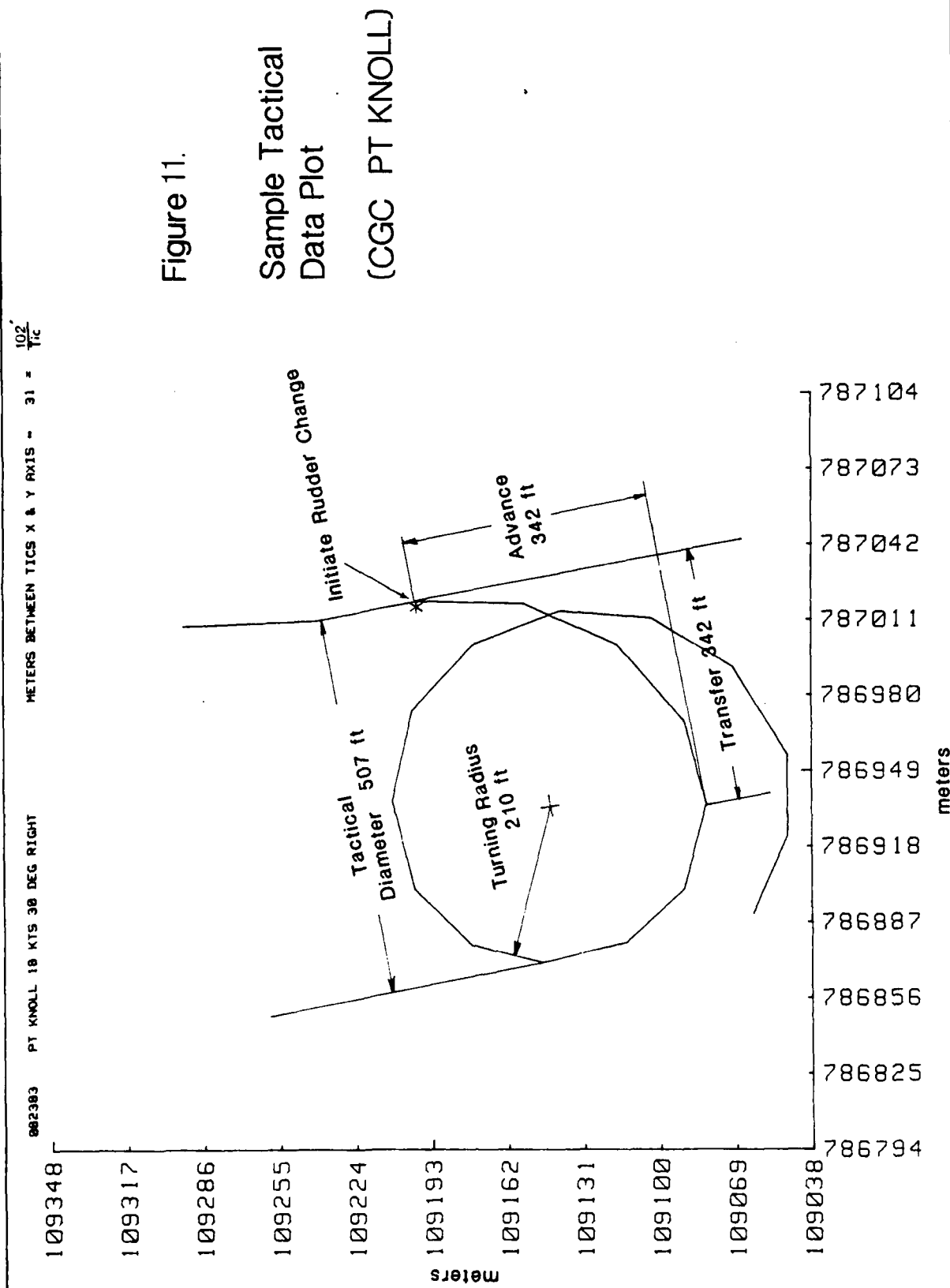


Figure 12.

Sample Tactical
Data Plot
(CGC CAPE FAIRWEATHER)



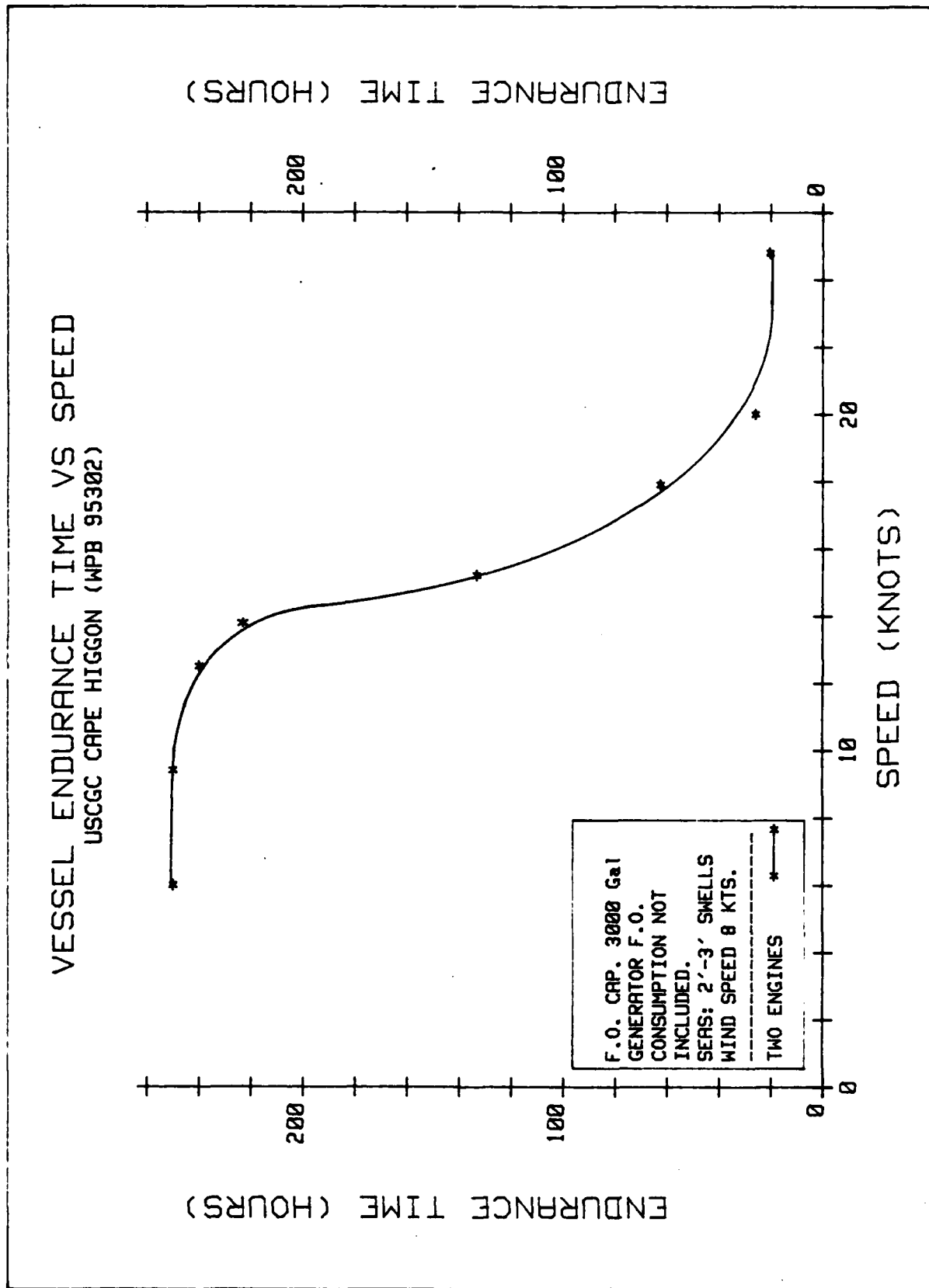


FIGURE 10 - CAPE HIGGON - ENDURANCE

SPEED VS MAXIMUM CRUISE DISTANCE USCGC CAPE HIGGON (WPB 95302)

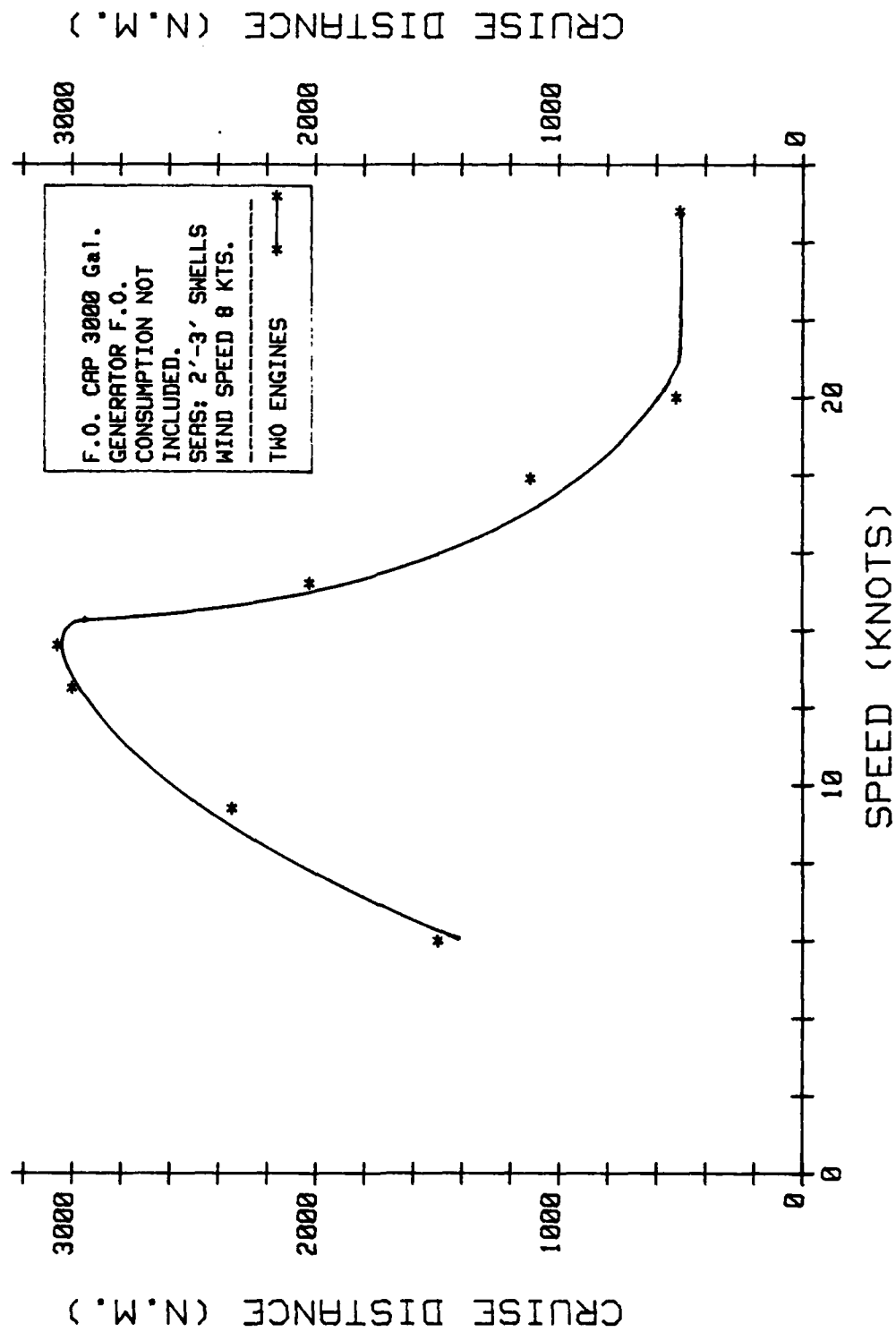


FIGURE 9 - CAPE HIGGON - CRUISING RANGE

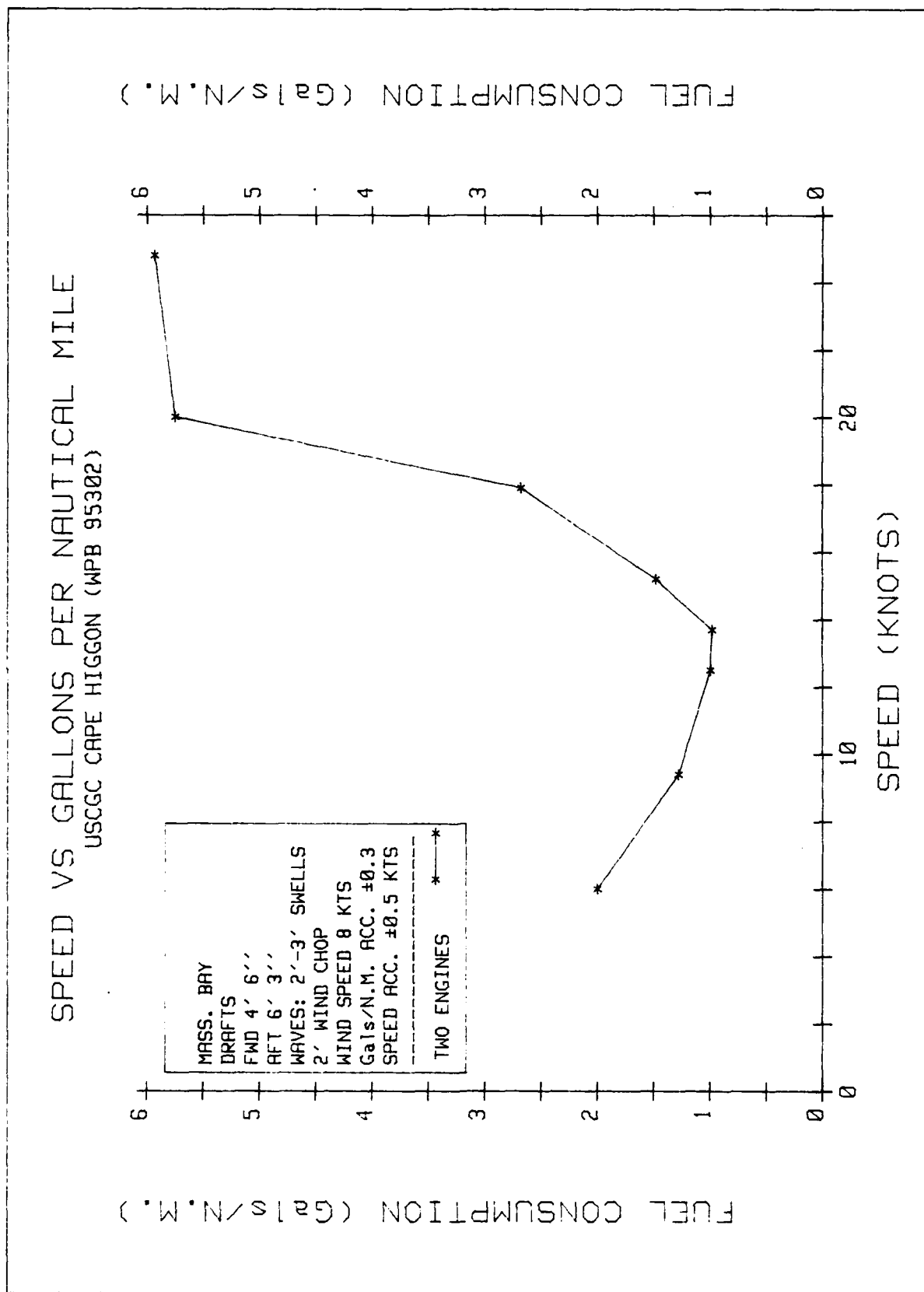


FIGURE 8 - CAPE HIGGON - FUEL EFFICIENCY

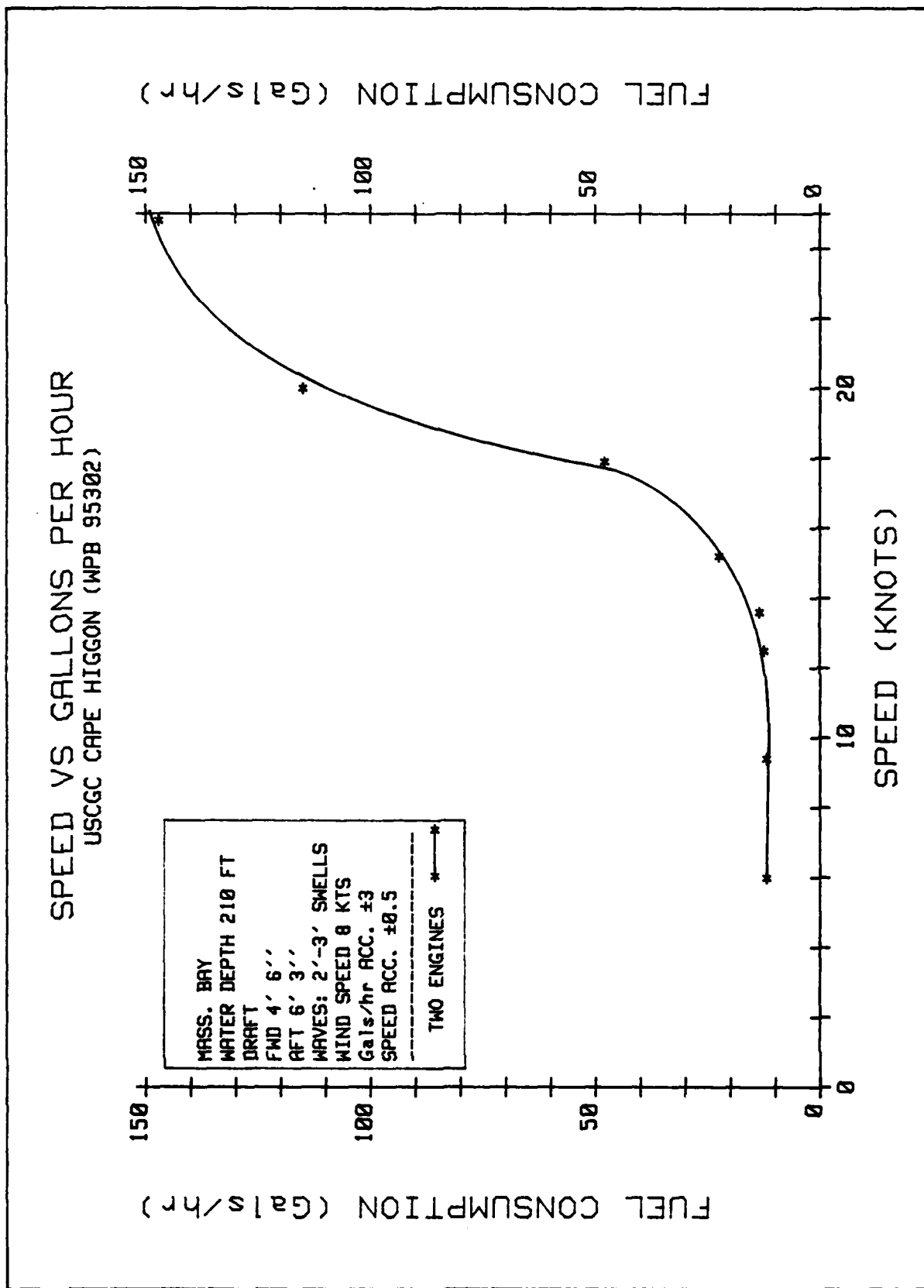


FIGURE 7 - CAPE HIGGON - FUEL CONSUMPTION

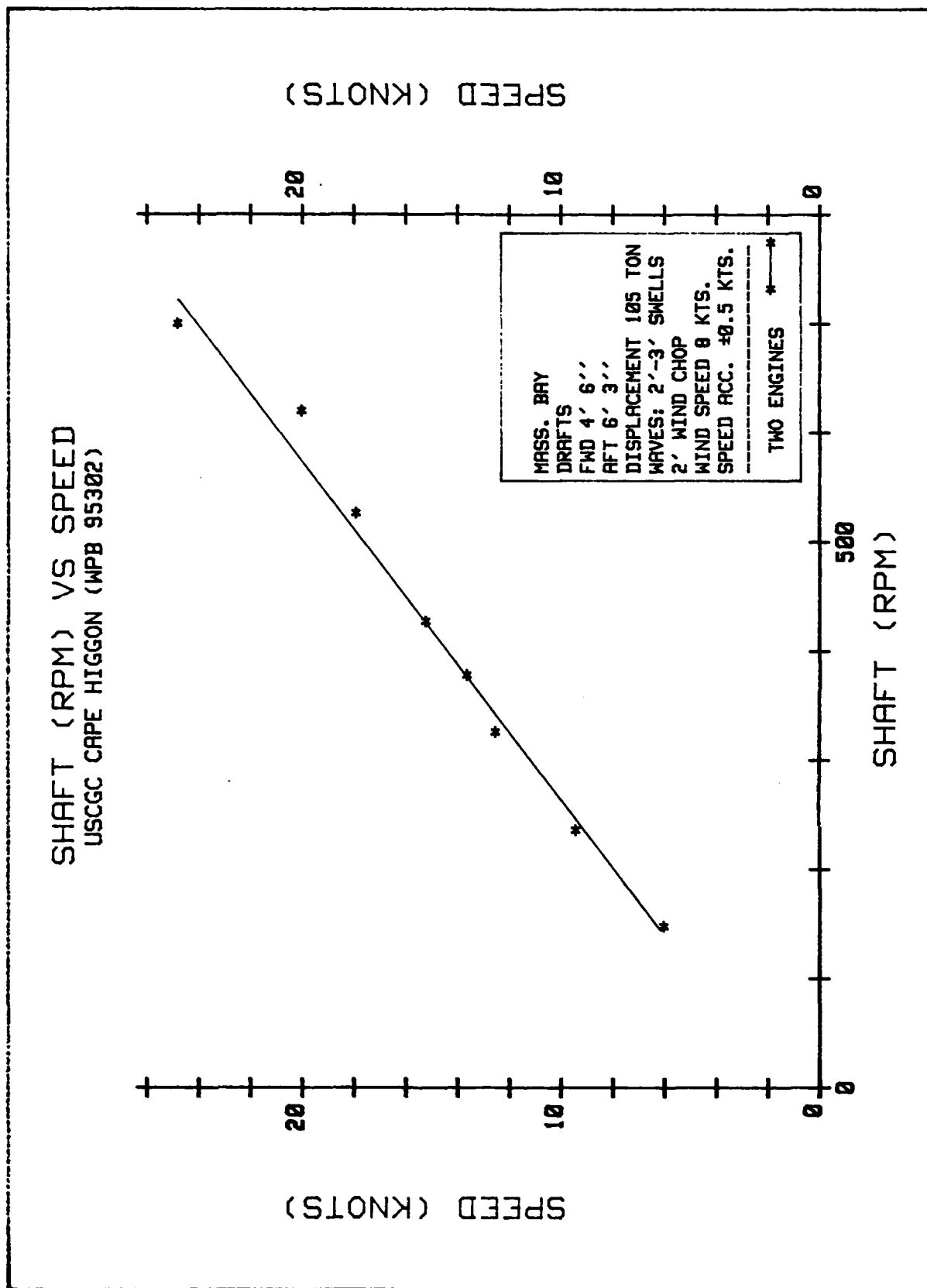


FIGURE 6 - CAPE HIGGON - SHAFT RPM VS. SPEED

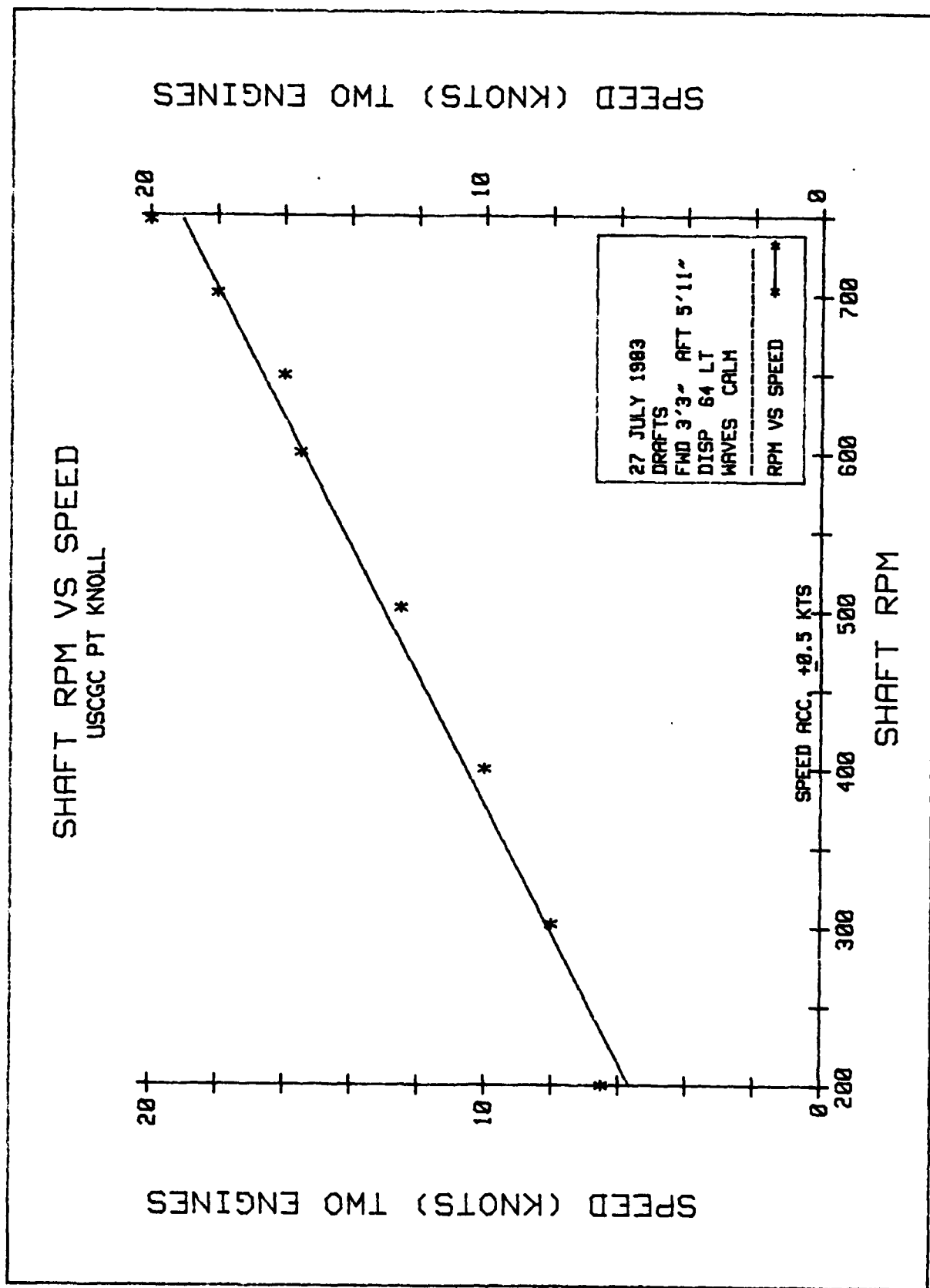


FIGURE 5 - POINT KNOLL - SHAFT RPM VS. SPEED

SPEED VS POWER USCGC PT KNOLL (WPB 82367)

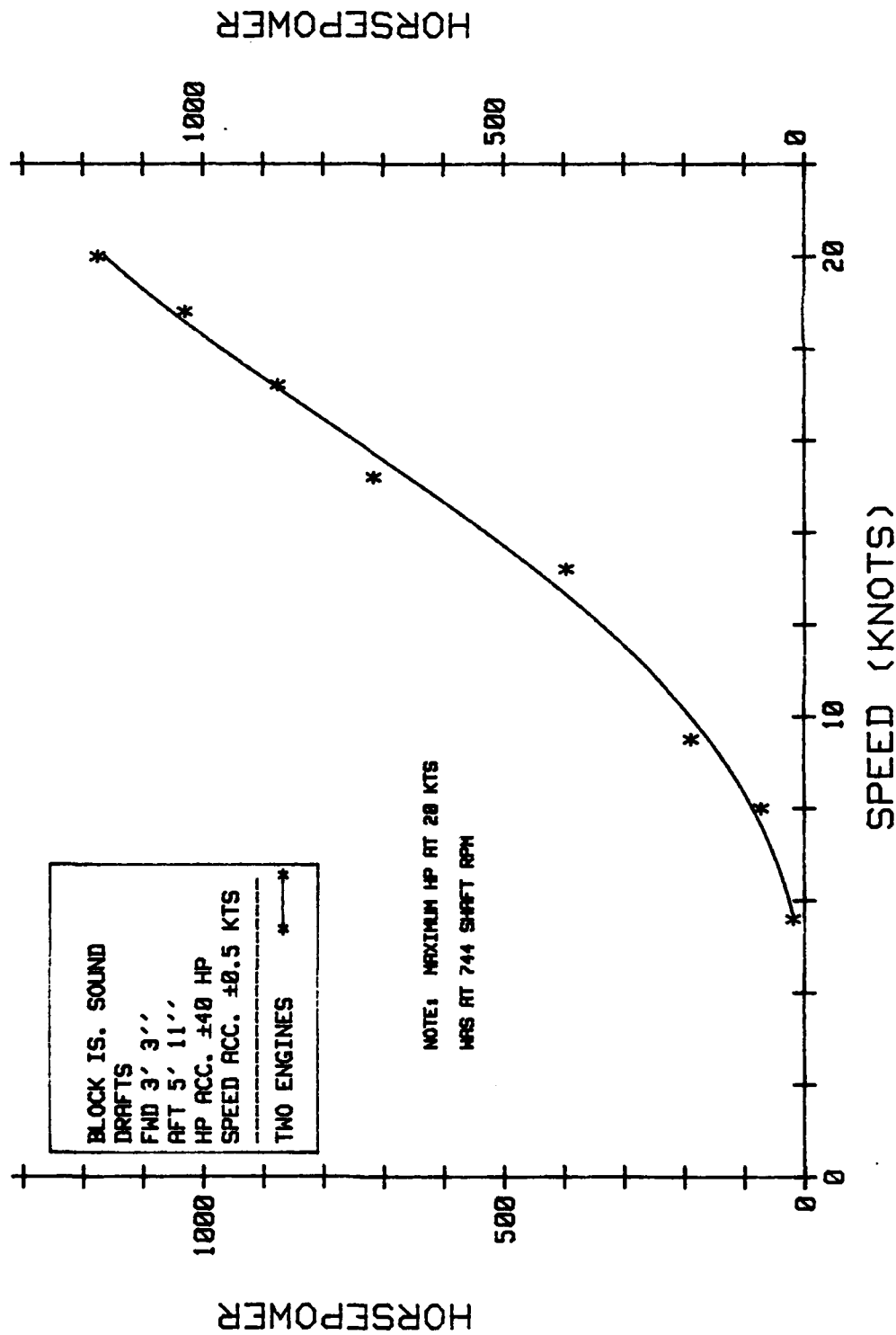


FIGURE 4 - POINT KNOLL - SPEED VS. HORSEPOWER

SPEED VS POWER USCGC CAPE HIGGON (WPB 95302)

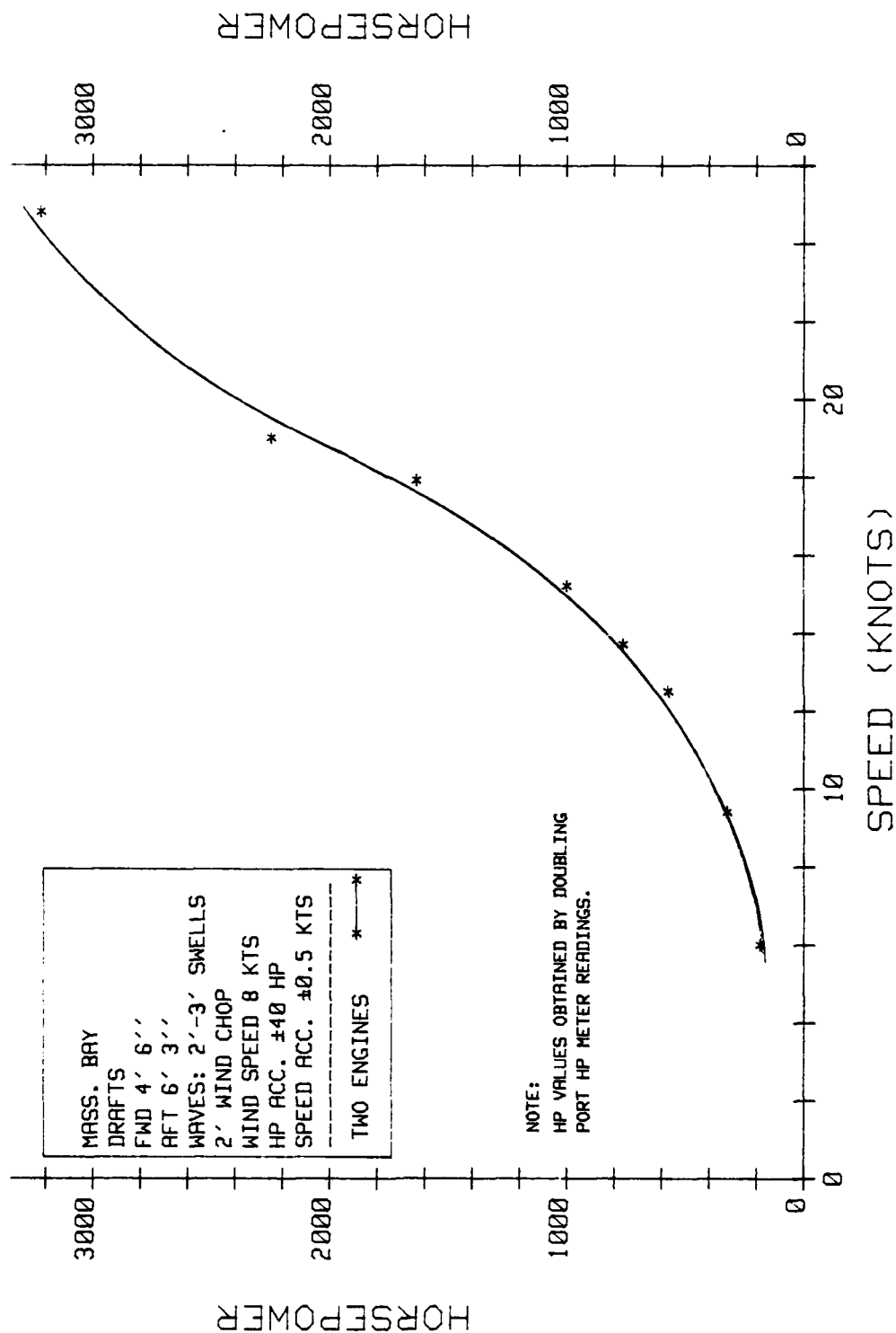


FIGURE 3 - CAPE FAIRWEATHER - SPEED VS. HORSEPOWER

In order to more fully visualize these tables of numbers relating to a ship's seakeeping and calm water performance abilities, various graphic techniques are utilized and presented in the text portion of this report.

5.0 CALM WATER PERFORMANCE

5.1 Speed vs. Power

The CAPE HIGGON is an "R" series 95' WPB with two new GM16V 149TI high speed diesel engines which replace four VT12-M Cummins engines. The port shaft HP meter operated consistently and accurately; however, the starboard system was unreliable. Results shown in Figure 3 were obtained by doubling the port HP meter readings. Measured shaft horsepower was significantly greater than advertised in technical manuals. At 24.8 knots, 1620 SHP was delivered on the port shaft when 1500 SHP is referenced as the maximum. This extra power may contribute to the relatively loud noise levels documented aboard the vessel.

The POINT KNOLL developed a maximum of 640 SHP per shaft (20 knots), as seen in Figure 4. This is under the rated SHP of 800 referenced in the ship's technical manuals. A plot of shaft RPM vs. speed of the PT. KNOLL is presented in Figure 5.

5.2 Speed and Fuel Consumption

Fuel consumption, measured by in-line fuel flow gauges, is presented in various ways to document the fuel efficiency, range, and endurance of the CAPE HIGGON (Figures 6 to 10.) This data is presented in tabular form in Appendix B, Table B-I. The 95' WPB has a clear optimum speed of 11.5 knots to maximize cruising range as seen in Figure 8. Note that fuel consumption of the diesel generators aboard the vessel was not measured.

Fuel consumption data was collected aboard the POINT KNOLL, however, it is not presented in this report because it is incomplete at speeds below 13 knots and unexplainably high compared to the CAPE HIGGON at moderate speeds. Since fuel consumption for a diesel engine was obtained by subtracting the discharge return flow to the fuel tank from the intake flow, resolution of fuel consumption at lower speeds is difficult to obtain accurately. An 82' "POINT" class cutter will be retested with a much more accurate meter system and results will be presented for its entire operating range in an addendum to this report.

5.3 Turning and Maneuverability

The tactical data obtained at 8, 13, and 18 knots, such as tactical diameter, advance and transfer distances for the 82' and 95' WPB are very similar as seen in Tables B-II and B-III in Appendix B. Graphic definitions of tactical terms are presented in representative tactical data plots (Figures 11 and 12) for the POINT KNOLL and CAPE FAIRWEATHER, respectively.

Spiral tests were conducted on both vessels at approximately 7 and 16 knots. The spiral test measures steady state yaw (turning) rates of a vessel as a function of rudder angle. A plot of these values is indicative of the course keeping stability and maximum turning rates of each vessel. The POINT KNOLL did not have a rudder angle indicator so the rudder angle

USCGC CAPE FAIRWEATHER &

USCGC CAPE HIGGON

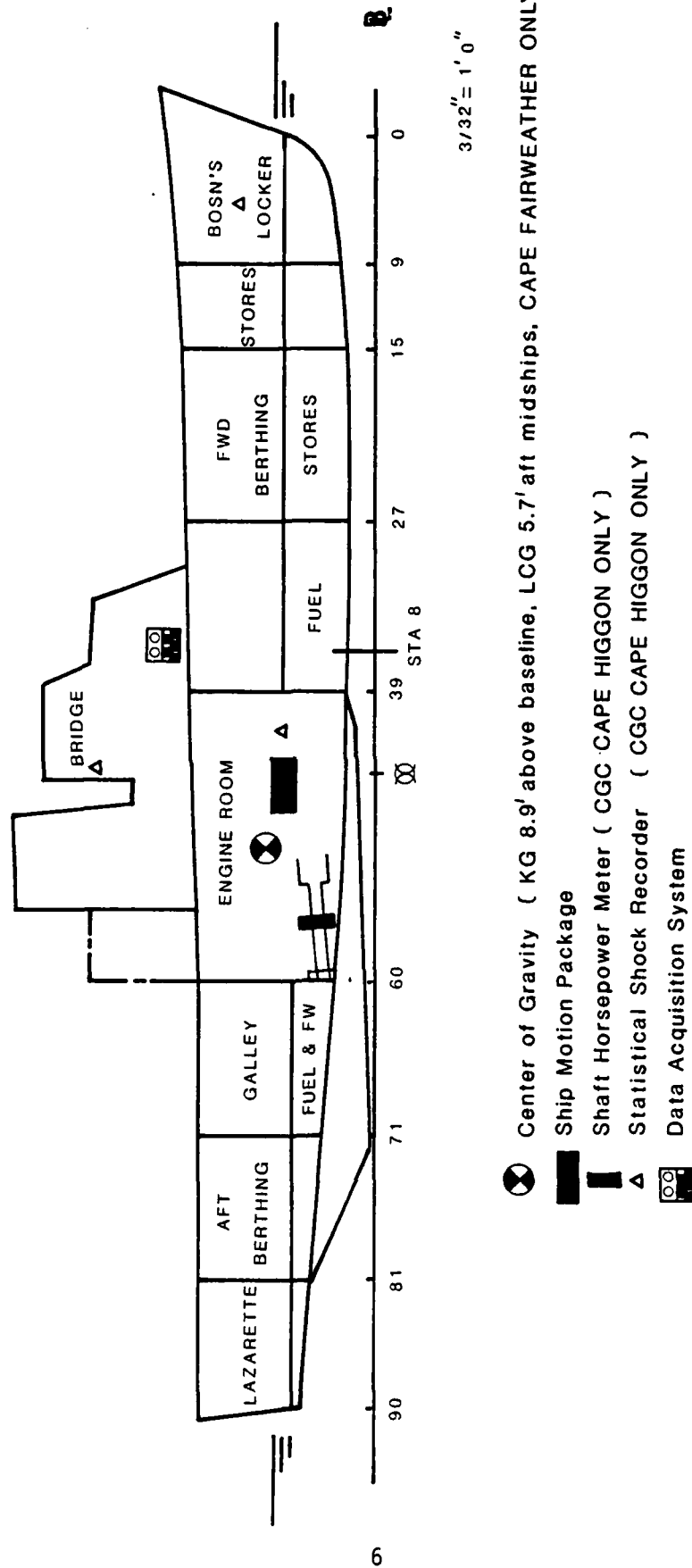


FIGURE 2. - 95' WPB Sensor Locations

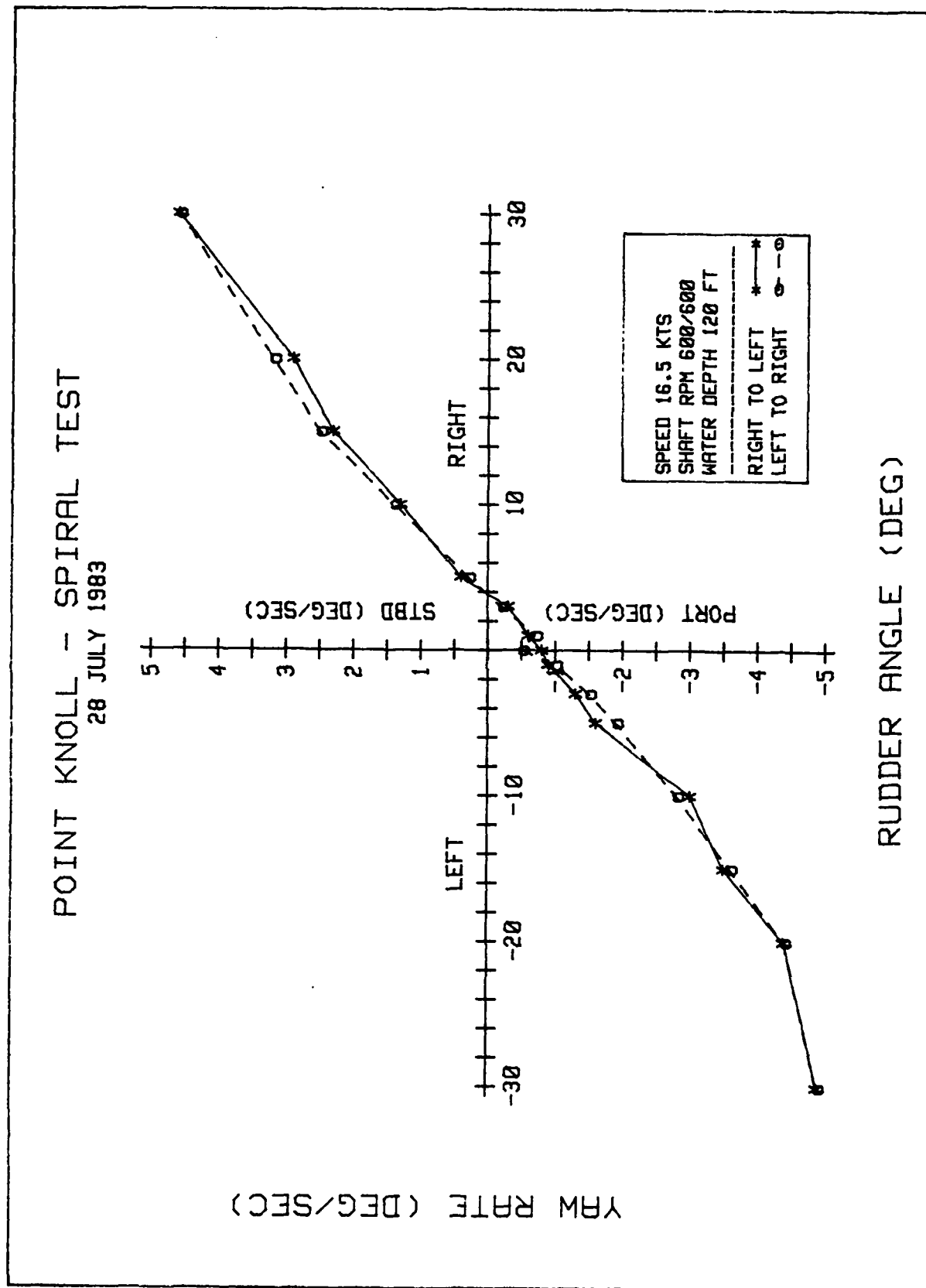


FIGURE 14 - POINT KNOLL - SPIRAL PLOT - 16.5 KNOTS

CAPE HIGGON - SPIRAL TEST
19 JANUARY 1983

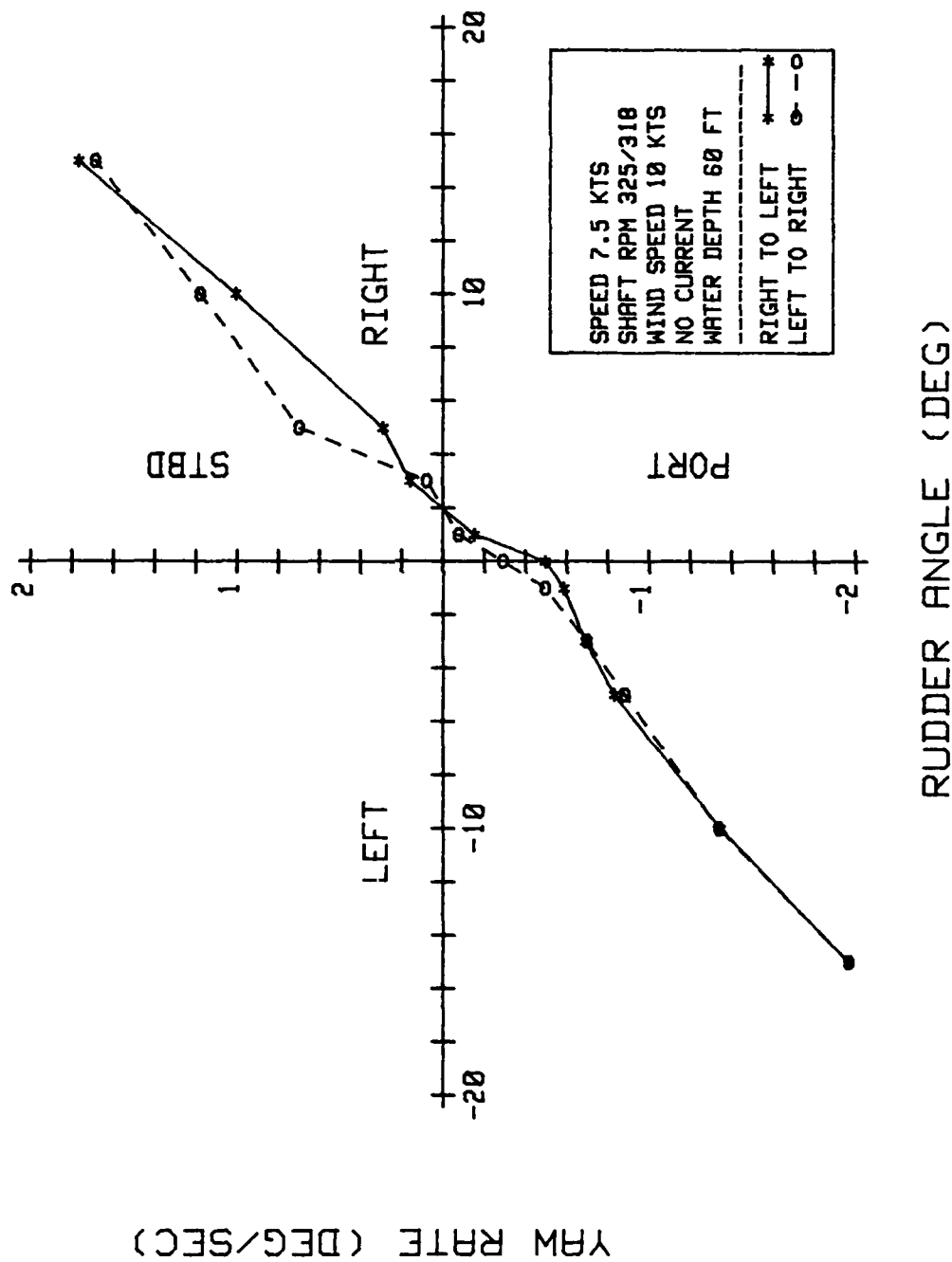


FIGURE 15 - CAPE HIGGON - SPIRAL PLOT - 7.5 KNOTS

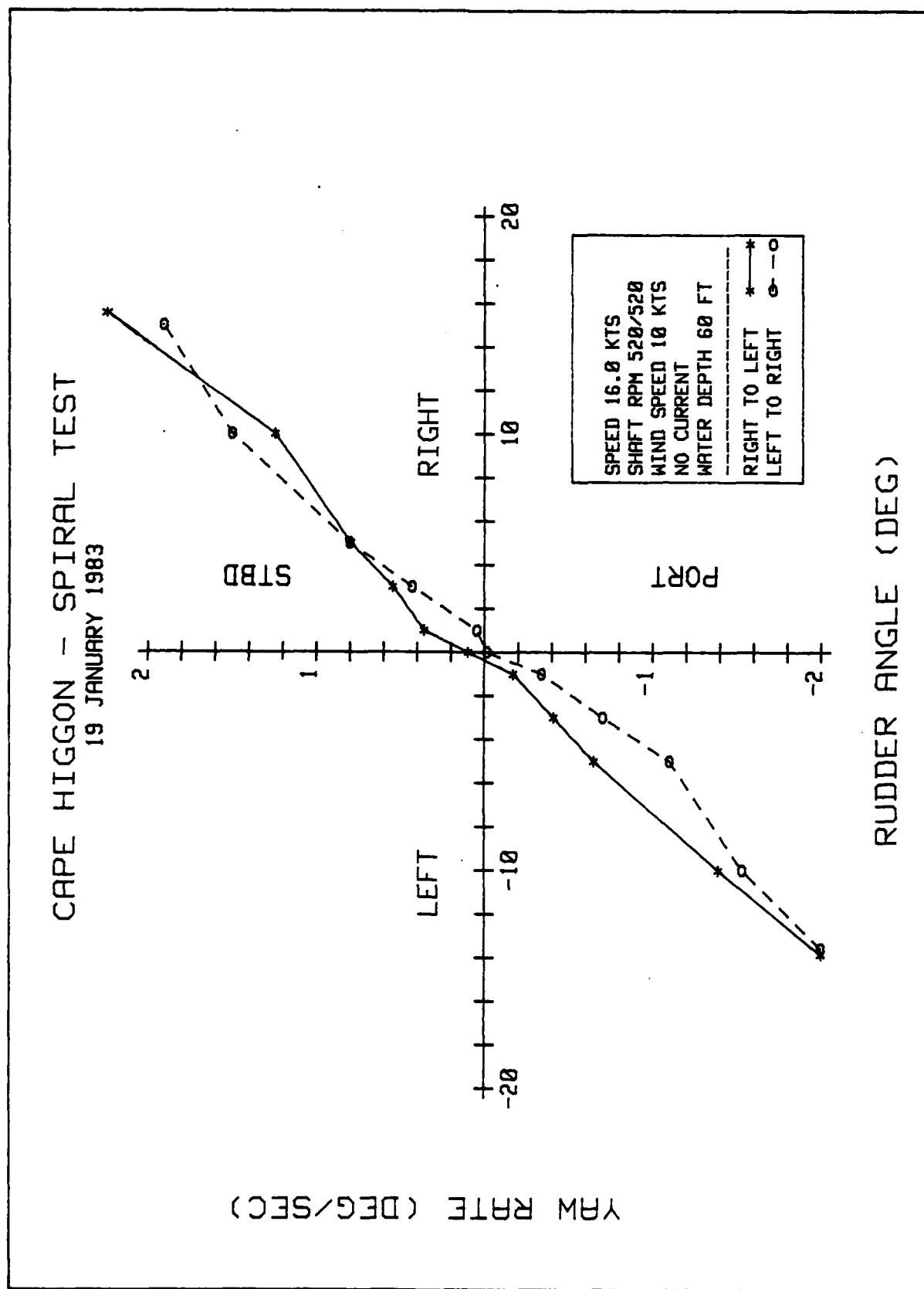


FIGURE 16 - CAPE HIGGON - SPIRAL PLOT - 16 KNOTS

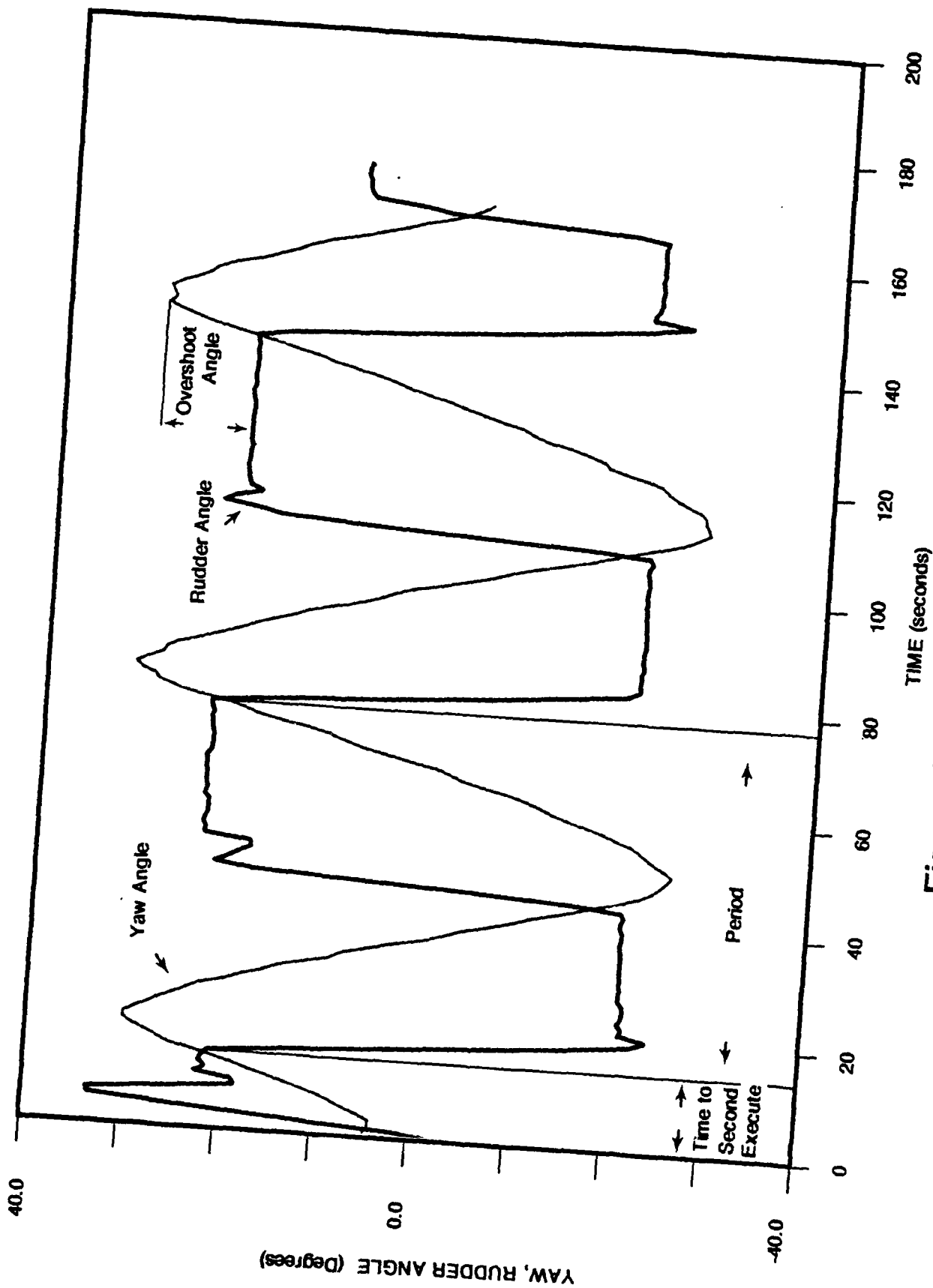


Figure 17. CAPE FAIRWEATHER
Zig-Zag Plot - 8 Knots

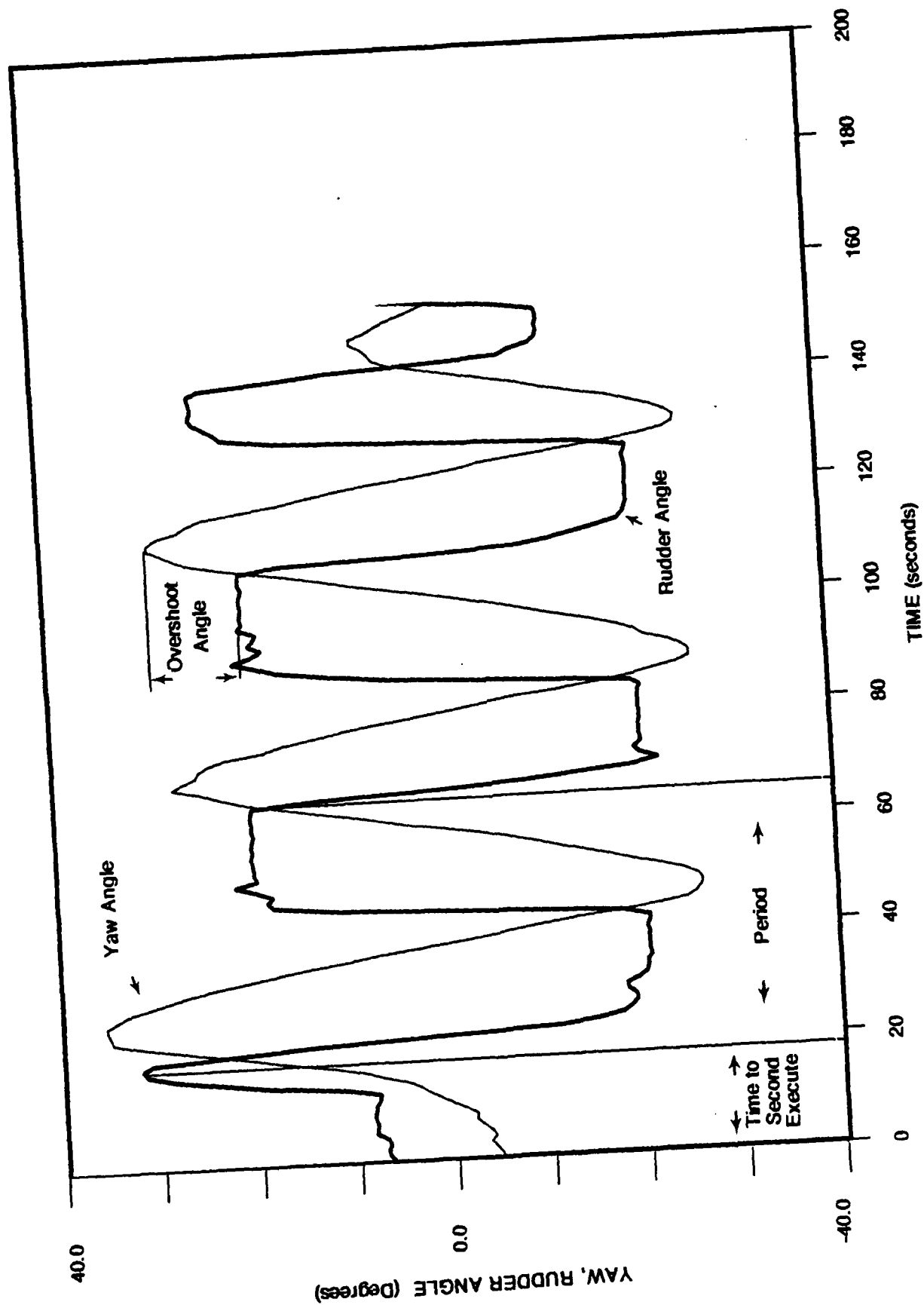


Figure 18. CAPE FAIRWEATHER
Zig-Zag Plot - 12 Knots

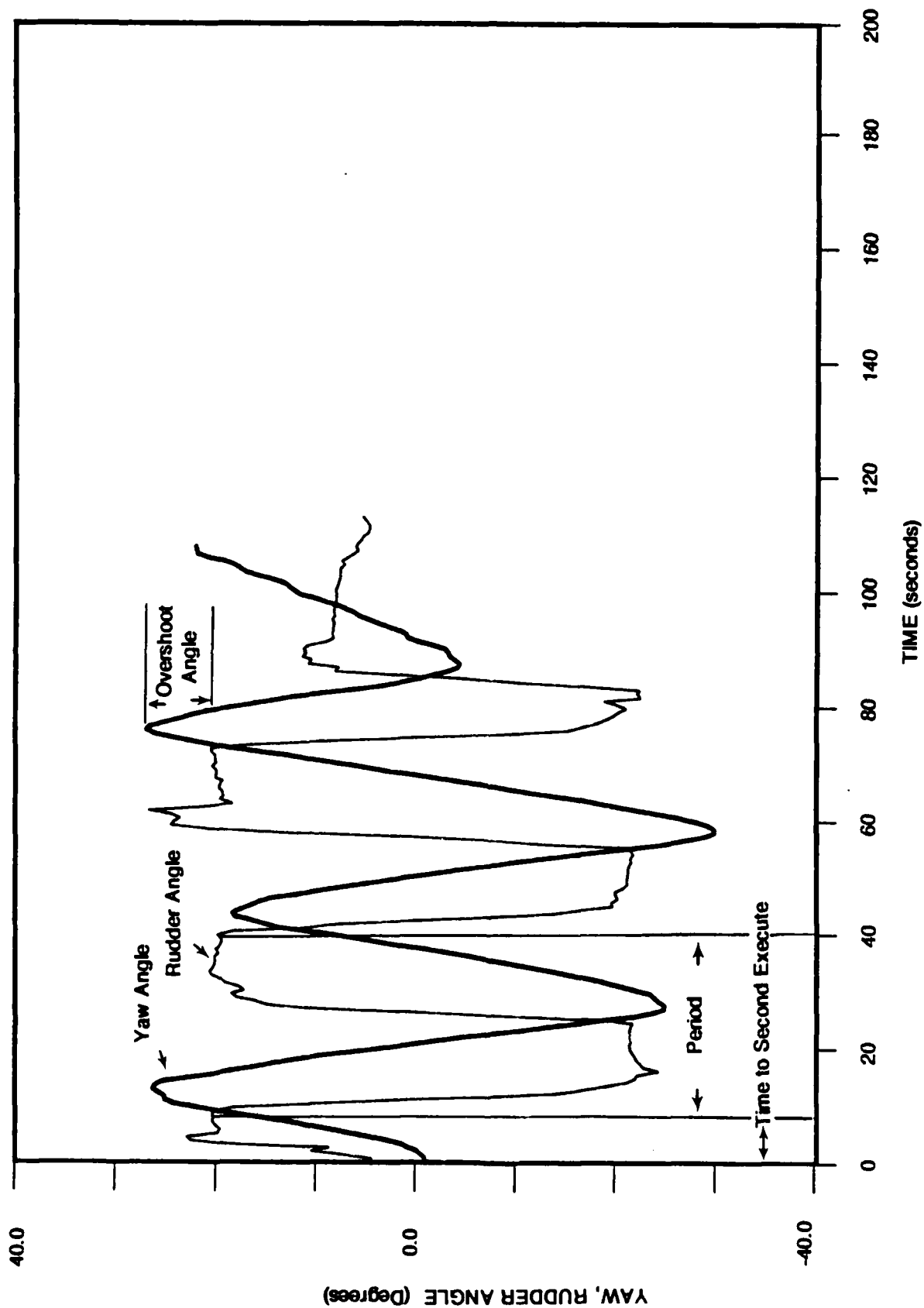


Figure 19. CAPE FAIRWEATHER
Zig-Zag Plot - 17.5 Knots

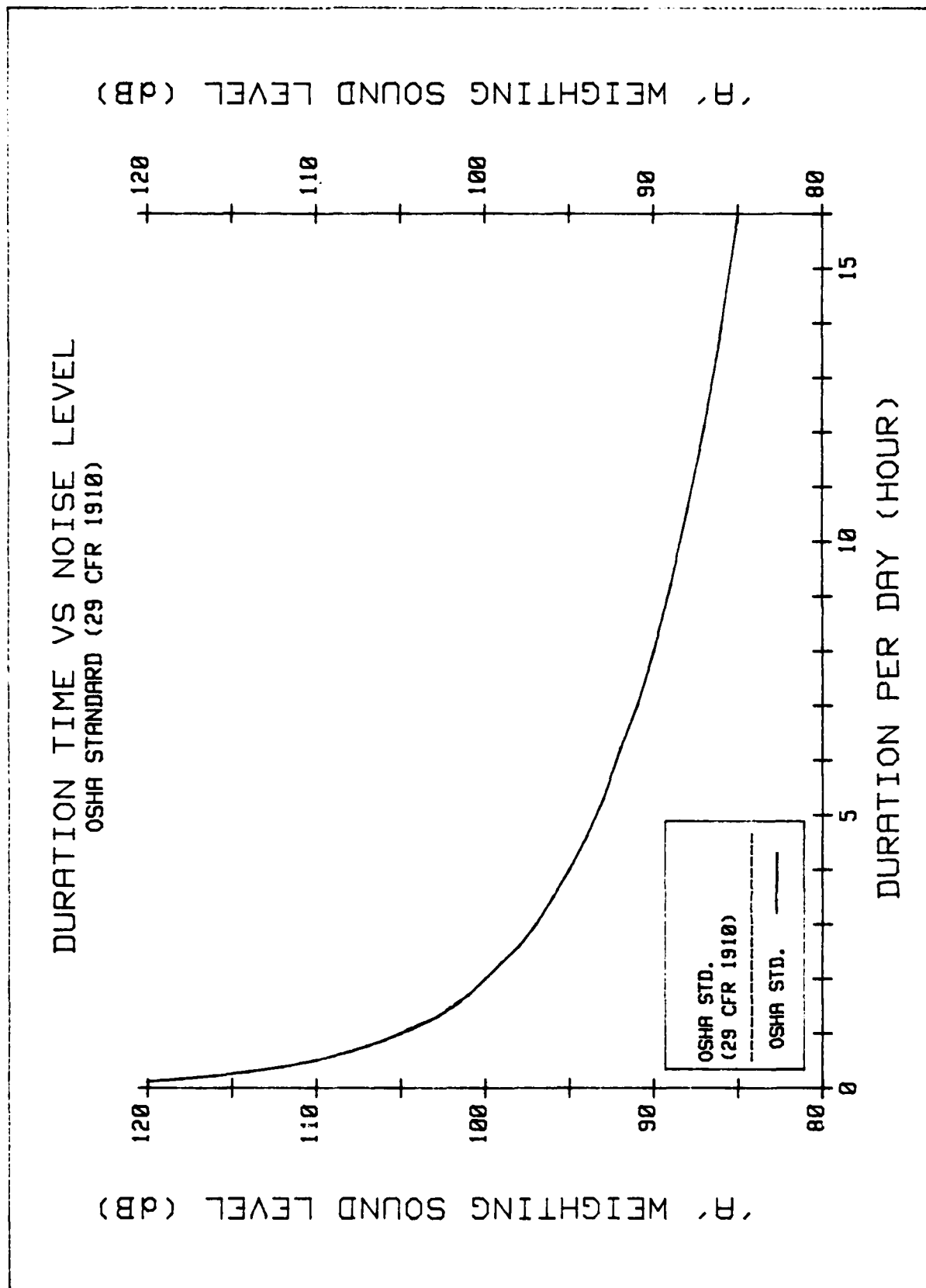


FIGURE 20 - OSHA NOISE DURATION STANDARD

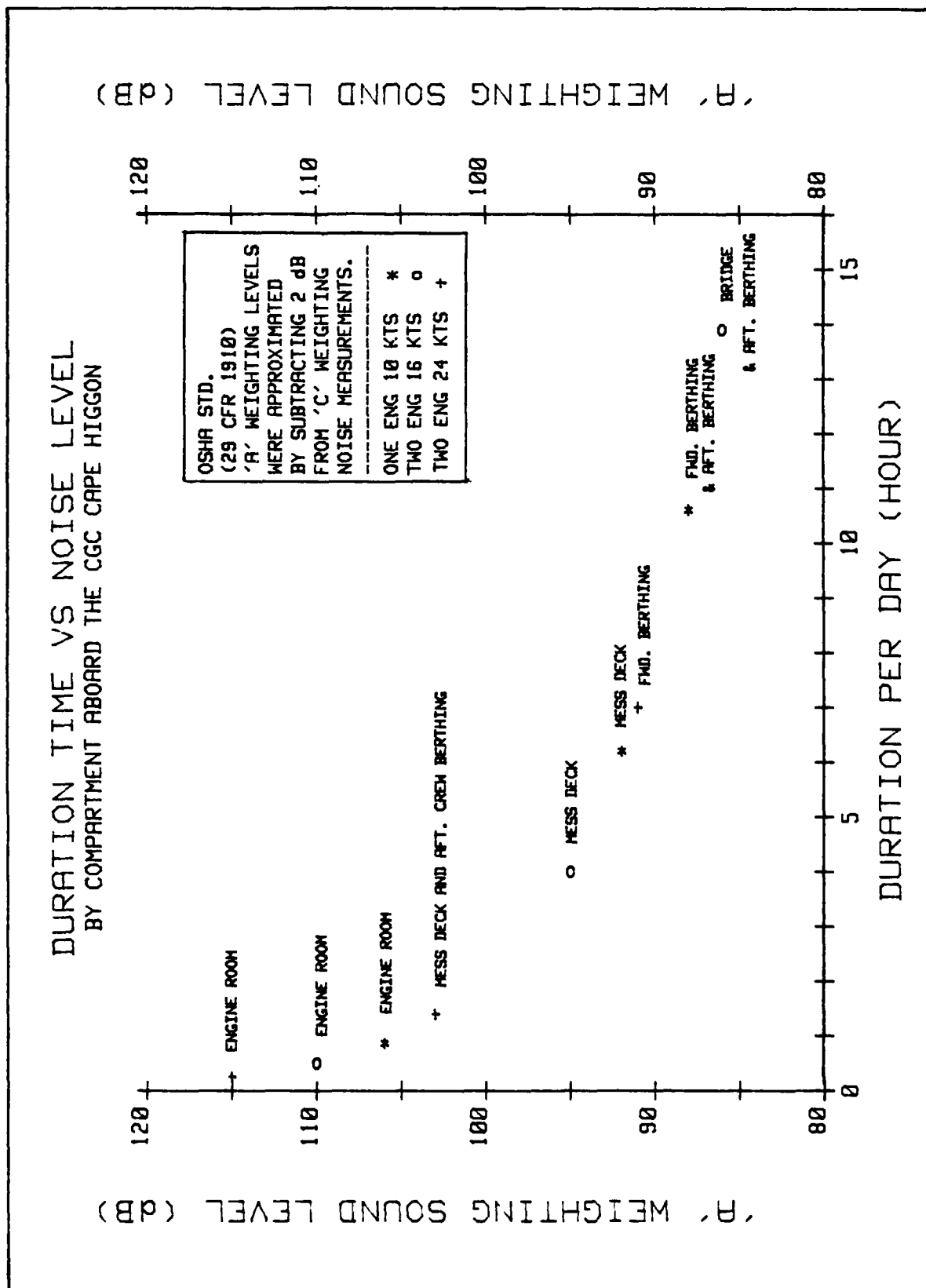


FIGURE 21 - CAPE HIGGON - NOISE LEVEL PLOT

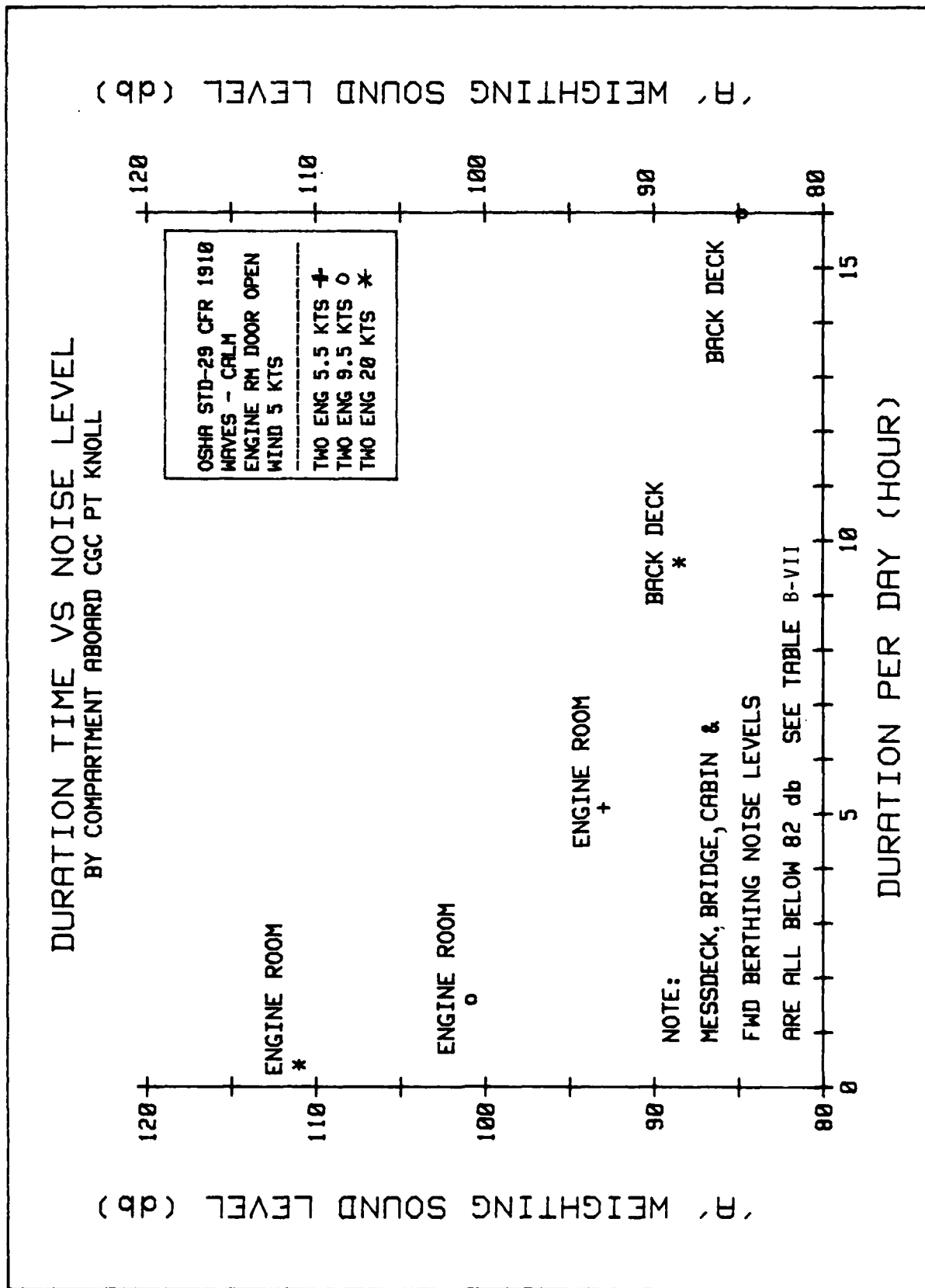


FIGURE 22 - POINT KNOLL - NOISE LEVEL PLOT

**PT KNOLL TOWING CAPE FAIRWEATHER
TOW LINE TENSION VS SPEED**

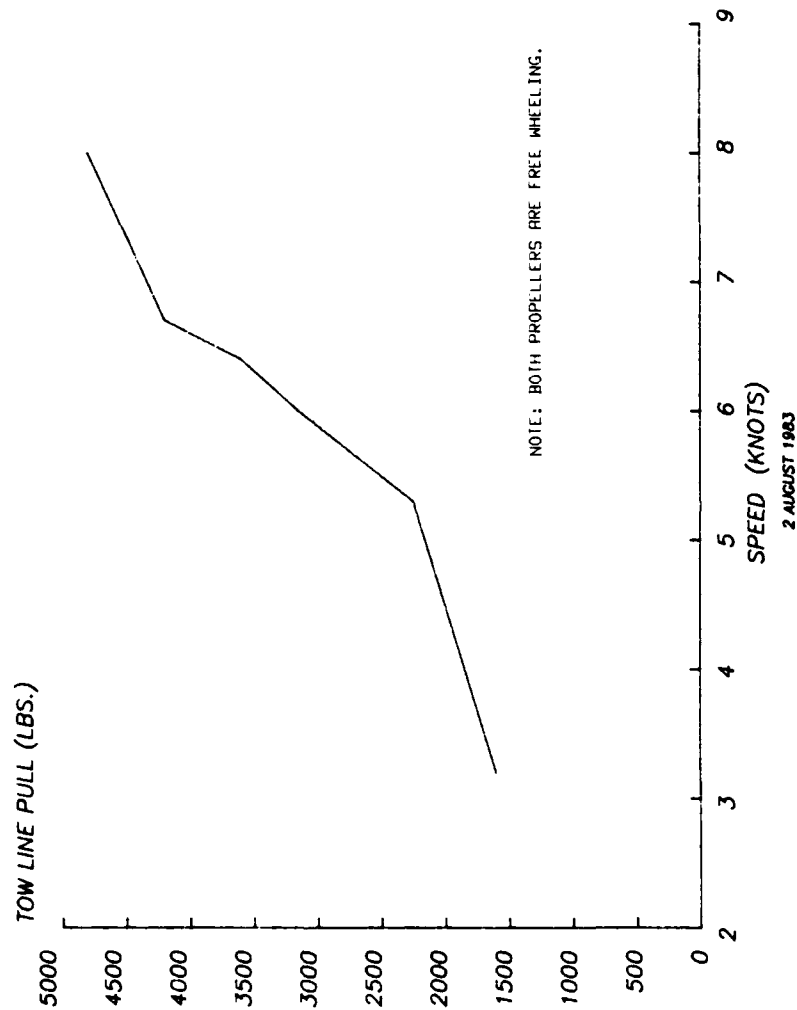


FIGURE 23 - POINT KNOLL TOWING CAPE FAIRWEATHER

WAVE HEIGHTS DURING WPB SEAKEEPING ENDECO 956 AND WAVE RIDER BUOY COMPARISONS

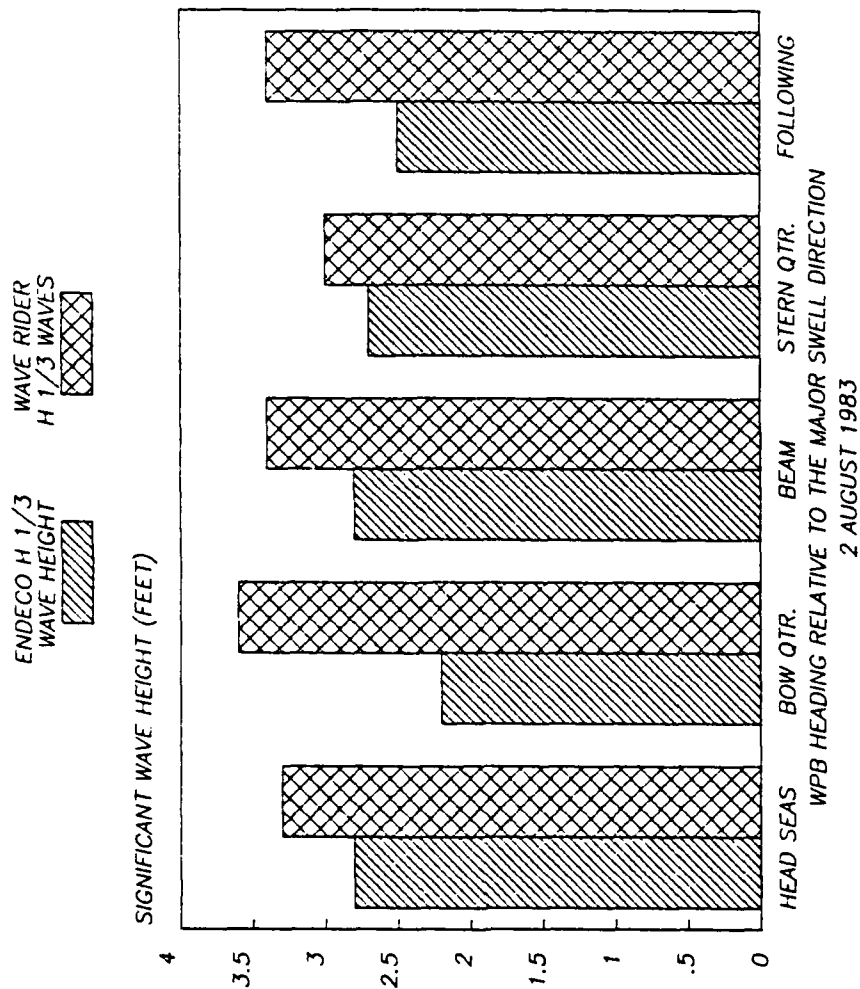


FIGURE 24 - WAVE HEIGHT COMPARISONS - ENDECO VS. WAVE RIDER BUOYS

QUICK-LOOK PLOT OF FREQUENCY/DIRECTION SPECTRUM
 ENTRIES ARE SCALED LINEARLY FROM 0 TO 50
 PEAK VALUE CORRESPONDS TO SPECTRAL DENSITY OF .028 (FT-SQ/HZ*006)

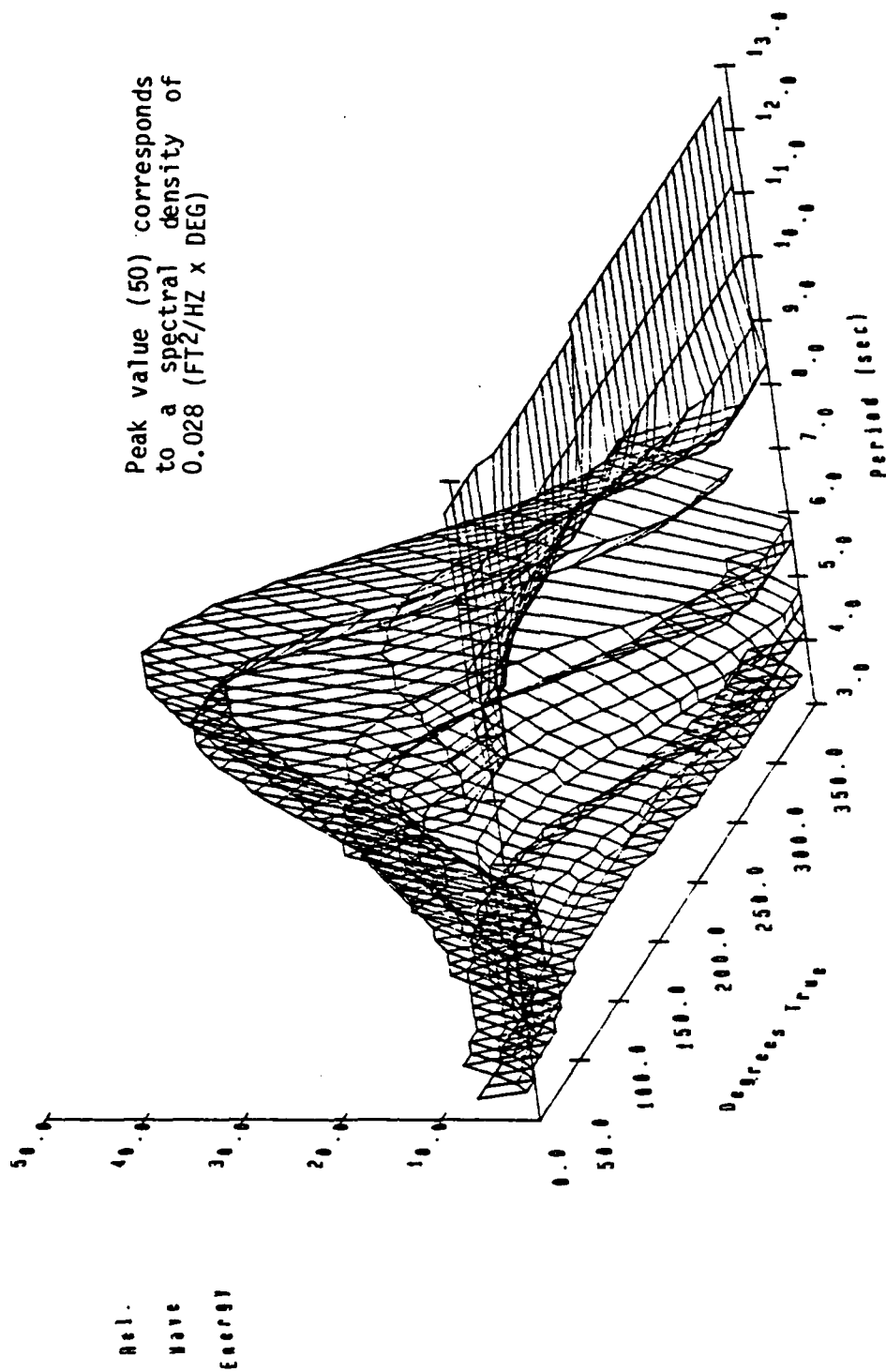
DIRECTION TRUE (DEGREES)																															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
70	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
80	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
90	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
100	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
110	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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130	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
140	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
160	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
170	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
180	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
190	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
200	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
210	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
220	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
230	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
240	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
250	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
260	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
270	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
280	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
290	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
300	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
310	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
320	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
330	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
340	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
350	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			

FREQUENCY HZ

2 AUGUST 1983

SIGNIFICANT WAVE HEIGHT 2.8 FEET

FIGURE 25 - FREQUENCY/DIRECTION WAVE ENERGY SPECTRUM FROM ENDECO 956 BUOY



Sea State During WPB Side by Side Seakeeping Test

2 August 1983

SIGNIFICANT WAVE HEIGHT 2.8 FEET

FIGURE 26 - 3D PERIOD/DIRECTION WAVE ENERGY FROM ENDECO 956 BUOY DATA

The Wave-Rider buoy deployed for the CAPE HIGGON seakeeping tests in January 1983 failed to operate properly, so the visual estimate of 4' significant swells was the only wave height information available. This failure may have been caused by the below freezing temperature exposure to the buoy on deck before deployment. Wave-Rider and Endeco 956 buoys both performed well during the side-by-side seakeeping evaluation in August. The buoys were placed at the center of the test area in Block Island Sound so that they were within three miles of the vessels at all times.

6.2 Side-by-Side Seakeeping: CGC CAPE FAIRWEATHER AND CGC POINT KNOLL

The side-by-side seakeeping runs of the CGC CAPE FAIRWEATHER and POINT KNOLL were conducted in 3 foot significant seas at constant speeds in five directions relative to the major swell; head, bow quarter, beam, stern quarter, and following seas. Ship motion data was collected for 20-30 minute runs on each leg. Polar plots of these seakeeping tests are presented in Figures 27 to 29. Tabular data is included in Appendix C, Table C-I.

The side-by-side polar plots, Figures 27 and 28, show that there is not a significant difference of roll and pitch motions between the 95' and 82' WPB's in three foot seas. Roll, pitch, and heave Response Amplitude Operators (RAO's) were computed for the runs conducted side-by-side at 16 knots in 3.0 foot significant seas. Heave data on the CAPE FAIRWEATHER was not collected due to equipment failure. Heave data is available and presented in Figure 32 for the CAPE HIGGON which was tested at 19 knots in a higher sea state, 4 feet. A description of the RAO calculations along with a listing of the computer program is presented in Appendix D.

6.3 CGC CAPE HIGGON - Seakeeping, Susceptibility to Slamming and Seasickness in 4 foot Head Seas.

Seakeeping runs similar to those of the side-by-side tests were conducted in 4 foot seas with the CAPE HIGGON in January 1983. Roll pitch and heave polar plots are presented in Figures 30-32. The tabular motion data is presented in Appendix C, Table C-II.

Three vertical statistical shock recorders were mounted on the CAPE HIGGON as seen in Figure 2. In addition to these sensors, a Bruel & Kjaer (B&K) Human Response Vibration Meter Type 2516 was used on the bridge to evaluate the ride quality in accordance with the ISO vertical axis Motion Sickness - Severe Discomfort (MS-SD) limit.

While proceeding for 10 minutes at 14 knots into 4-foot head seas, 1 slam exceeded 1 g at the bow while no slams exceeded 1 g on the bridge or in the engineroom at the center of gravity (CG). THE B&K meter on the bridge registered a mean weighted vertical acceleration level of 0.40 g's. The MS-SD limit was reached in 2 minutes.

While proceeding at 23 knots again into 4-foot head seas for 10 minutes, 5 slams exceeded 1 g at the bow. Three of those 5 slams exceeded 3 g's and one slam exceeded 4 g's. No slams exceeded 1 g on the bridge or in the engineroom. The B&K meter registered a mean vibration level of 0.46 g's on the bridge and again 100% of the MS-SD limit was reached in 2 minutes.

TABLE B-II
USCGC POINT KNOLL
TACTICAL DATA

Degrees Rudder	Distances in Feet			
	Advance	Transfer	Tactical Diameter	Turning Radius
<u>SPEED 8 KNOTS</u>				
100° Left	523	443	981	355
100° Right	300	274	1181	378
200° Left	--	--	--	--
200° Right	426	400	577	155
300° Left	360	267	480	209
300° Right	342	342	507	210
<u>SPEED 13 KNOTS</u>				
100° Left	795	392	905	392
100° Right	695	435	880	285
200° Left	527	330	546	187
200° Right	594	347	573	152
300° Left	413	503	506	139
300° Right	--	--	--	--
<u>SPEED 18 KNOTS</u>				
100° Left	979	773	1304	365
100° Right	628	491	1144	641
200° Left	362	256	565	275
200° Right	444	270	609	326
300° Left	150	345	424	150
300° Right	149	227	478	253

TABLE B-I
CALM WATER PERFORMANCE WITH TWO ENGINES
USCGC CAPE HIGGON

Shaft RPM	Speed (Knots)	Total Fuel Flow* Gal/Hr	Cruising Range* (NM)	Endurance* (Hrs)	Gal/nm*
150**	6.0	12.0	1500	250.0	2.0
235	9.4	12.0	2344	250.0	1.3
327	12.5	12.5	3000	240.0	1.0
379	13.7	13.5	3061	222.2	1.0
425	15.2	22.5	2027	133.3	1.5
525	17.9	48.0	1119	62.5	2.7
620	20.0	115.0	521	26.1	5.8
700	24.8	147.0	506	20.4	5.9

Note: DRAFTS; FWD 4'6", AFT 6'3", DISPLACEMENT 105 LT
Seas 2-3' swells, wind 8 kts.

* Usable fuel 3000 gallons. Does not include fuel consumption of one 30 kw generator. One generator operating would consume approximately 3 gal/hr diesel fuel oil.

** Low clutch engaged.

APPENDIX B
CALM WATER PERFORMANCE

torque. A transmitter collar and antenna are bolted to the shaft in order to power and transmit FM signals from the strain gaugebridge. Three simultaneous analog outputs are provided at the readout box (Torque, HP and RPM). Calibration using a shunt resistor is usually conducted because a known torque load is difficult to apply to a vessel in the water. This method simulates a torque load by shunting a gauge with a known value of resistance.

SPECIFICATIONS

Accuracy: Torque	+ 1% of full scale
RPM	\pm 0.25% of full scale
Horsepower	\pm 1.5% of full scale

STATISTICAL SHOCK RECORDER Intertia Switch, Inc, NY, NY

This mechanical device measures shock in one axis which exceeds 1g acceleration. Each unit has four separate mechanical measurement systems which register a shock above their calibrated limits (i.e., 1, 2, 4, 6 g's)

SOUND LEVEL METER TYPE 213H Bruel and Kjaer Marlborough, MA

This hand-held sound level meter measures levels from 50 to 130 dB with A or C weighting filters. It can be used with fast or slow response. Calibration is done by using a Sound Level Calibration unit Type 4230. The sound pressure level of the calibrator is 93.6 dB.

LOAD CELL MODEL 450D Sensotec, Inc. Columbus, OH

This load cell used to measure towline force. It gives a digital output of force in pounds as well as an analog output. A built-in shunt calibration circuit is utilized to set up the digital indicator box.

Range: 0-50,000 lbs
Accuracy: + 50 lbs
Output: 0-5 volts

MINI-RANGER TRACKING SYSTEM Motorola, Inc. Tempe, AZ

This tracking system has 3 fixed reference stations and up to 13 mobile reference stations. One mobile station was placed on the test vessel. The control station on shore collects the ship position data using an HP9845 computer. Accuracy is 3-10 yards depending upon location of reference stations.

Significant Wave Height ($H_{1/3}$) and significant period as well as a plot of wave energy vs. frequency and direction. This allows for a determination of the major swell direction and quantification of the extent of a unidirectional or confused sea state. Directional accuracy is $\pm 10^\circ$. It can be moored with an accumulator mooring system for long-term monitoring situations.

HUMAN-RESPONSE VIBRATION METER
Type 2512 Marion, MA Bruel &
Kjaer (B&K)

Measures vibration from a tri-axial accelerometer for the evaluation of vibration on the human body in agreement with current ISO standards for Hand-Arm and Whole-Body (including motion sickness) measurement. The complex relationship between level, frequency and time is automatically taken into account in the computation of equivalent continuous vibration level and exposure dose. Outputs are printed on thermal paper with the use of a Alphanumeric Printer type 2312. Outputs are automatically printed at preselected intervals in the form of: Current Time, Elapsed Time, Peak Acceleration (DB), Equivalent Exposure (DB) and Percent of a particular ISO standard selected which has been reached at that elapsed time.

TRIAXIAL SEAT ACCELEROMETER
Type 8322
(used with B&K Meter Type 2512)

This accelerometer is especially designed for detecting vibration motion in connection with the measurement of whole-body vibration and can be put under the buttocks of a seated person.

Frequency Range: 0.1 Hz to 2 kHz ($\pm 5\%$)

Charge Sensitivity: $1 \text{ pC/ms}^{-2} \pm 2\%$
10 pC/g

Piezoelectric Material: PZ27

Delta Shear Configuration

FUEL FLOW METERS
HEADLAND
Racine, WI

In-line flow meters are direct reading units requiring no electrical connections or read-out devices. Scales are based on a specific gravity of 0.84 for fuel oil. Accuracy within $\pm 5\%$ of full scale.

HORSEPOWER METER 1202A (2)
ACUREX AUTODATA,
Mountain View, CA

The 1202A measurement system measures shaft torque and RPM and calculates horsepower from that information ($HP = \text{Torque} \times \text{RPM} \times \text{Constant}$). The shaft is strain gauged for

APPENDIX A

DESCRIPTION OF INSTRUMENTATION

EQUIPMENT	DESCRIPTION
<u>SHIP MOTION PACKAGES (2)</u> <u>HUMPHREY, Inc.</u>	This unit consists of a vertical gyro, a vertically stabilized three-axis accelerometer assembly, a directional gyroscope, a three-axis rate gyro assembly and all necessary power supplies and power switching relays. Nine outputs are available at + 1 or + 5 volts full scale with or without a 10 HZ low pass filter. Full-scale outputs can be varied as the table below indicates.
Pitch Angles	+ 45°, 25° or 10°
Roll Angles	± 45°, 25° or 10°
Yaw Angles	± 175°
Pitch and Roll Rate	± 60, 30 or 10 deg/sec
Yaw Rate	± 30, 10 or 5 deg/sec
Surge & Sway Acceleration	± 1.0 or 0.5 G's
Heave Acceleration	± 2.0 or 0.5 G's
<u>STORE 14D ANALOG TAPE RECORDER</u> <u>(2)</u>	This analog tape recorder can record up to 14 channels including one voice channel which records on channel 14 and overruns data if recorded on that channel. It has variable speeds from 15/16 IPS up to 60 IPS. It can attenuate signals from 0.1 to 20 volts peak to peak normalizing the recorded signal to 1 volt peak to peak output.
<u>WAVE RIDER BUOY</u>	This wave height buoy transmits a continuous signal which is received and converted to analog output at any site usually on board the test vessel. The output signal is 1 volt per meter of wave height. The buoy is deployed and allowed to free float and drift during the 2-4 HR seakeeping trials. It can be moored with an accumulator mooring system for long-term monitoring situations.
<u>ENDECO 956 WAVE TRACK BUOY</u>	This orbital following wave buoy measures wave height and direction. It transmits three digital signals; wave height, buoy tilt (East-West), and buoy tilt (North-South) to a remote receiver usually deployed with the test vessel. The digital signals are recorded and analyzed using an Otrona 8:16 microcomputer. The data can be analyzed using either a "LONGUEST-HIGGONS" or "DIGITAL BAND PASS FILTERING" method. The output is

REFERENCES

1. Goodwin, M.J. "General Test Plan for Marine Vehicle Testing," USCG R&D Center Report, June 1981.

7.0 SUMMARY

There is very little difference in roll and pitch motions between the 95' and 82' WPB classes in 3 foot seas. Heave attenuates significantly on both class vessels when headings, relative to the waves, changed from head and bow quarter seas to slower wave encounter frequencies during beam, stern quarter and following seas steaming.

The CAPE HIGGON had very loud noise levels at moderate and high speeds, which are a potential hazard in living spaces. This is not the case on the POINT KNOLL, which had relatively quiet noise levels in living spaces.

The 95' and 82' WPB Class vessels demonstrated adequate rudder and maneuvering control. Tactical data for both vessels tested were very similar.

The RAO's calculated are useful in documenting the motion response characteristics of the vessels tested. They are misleading at very low frequencies of encounter (below 0.1 HZ) and thus should be used with caution when extrapolating motion data from them.

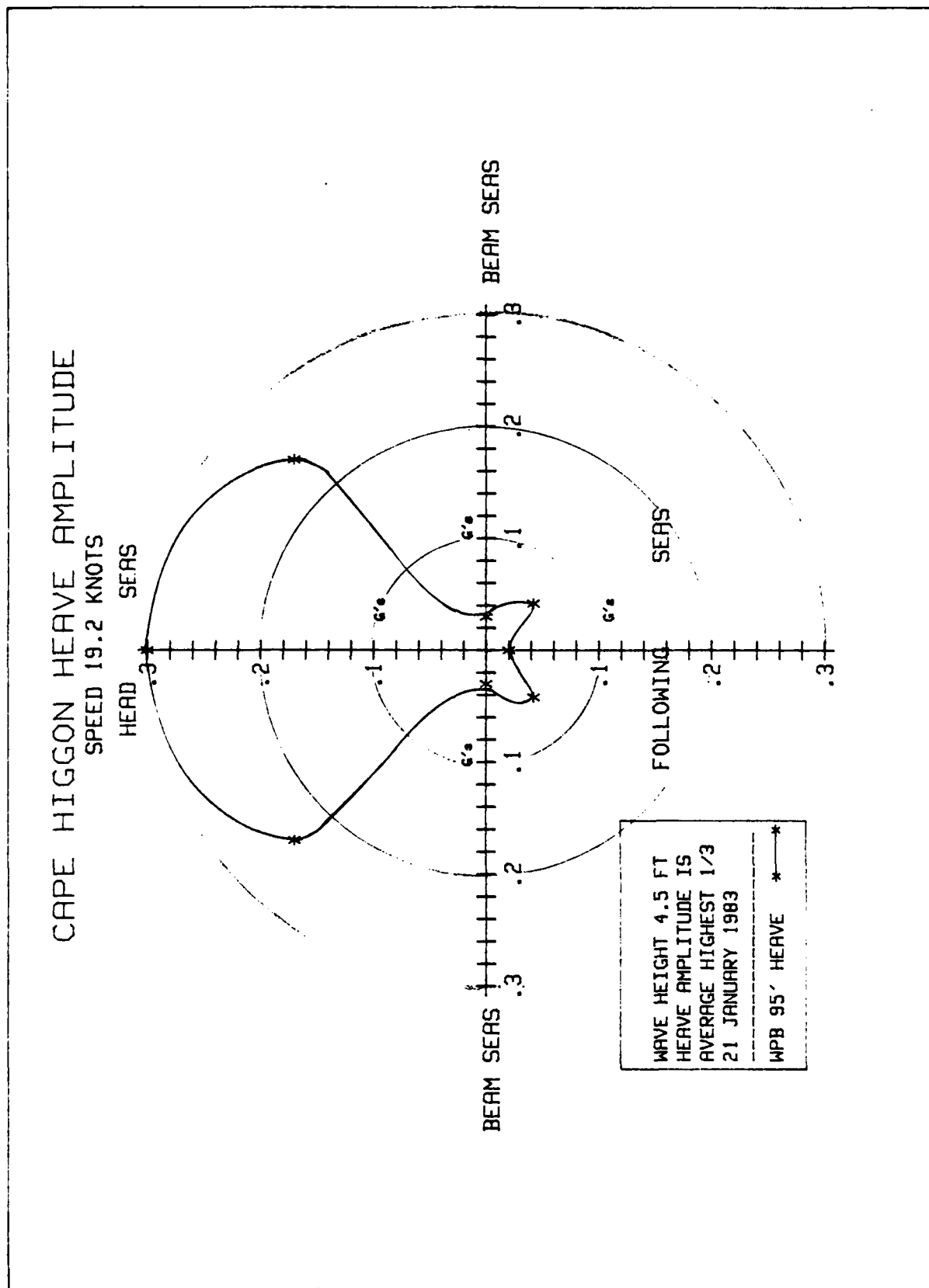


FIGURE 32 - POLAR PLOT - CAPE HIGGON HEAVE AMPLITUDE AT 19.2 KNOTS

PT KNOLL HEAVE ACCELERATION AMPLITUDE

SPEED 16 KNOTS

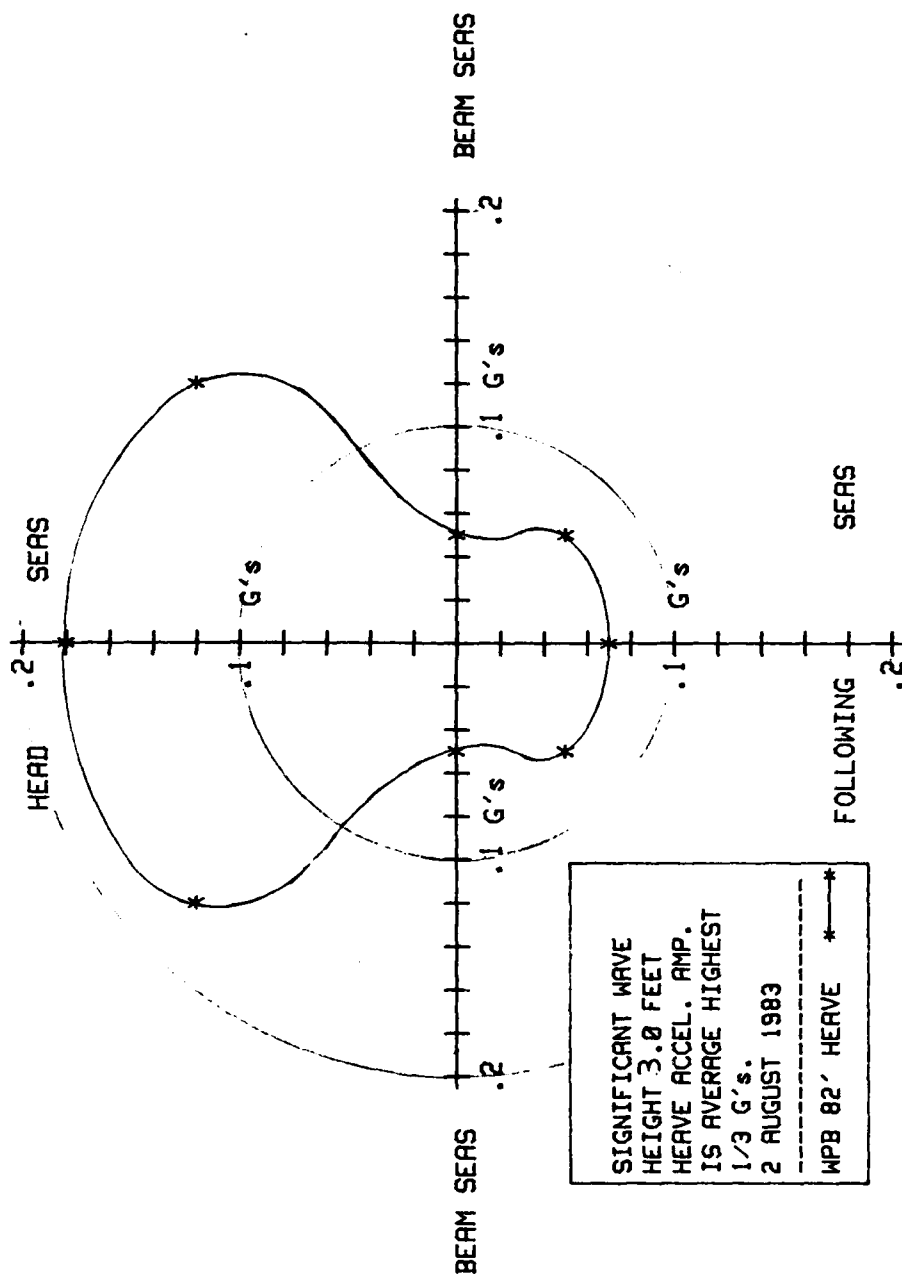


FIGURE 29 - POLAR PLOT - POINT KNOLL HEAVE ACCELERATION AMPLITUDE AT 12 KNOTS

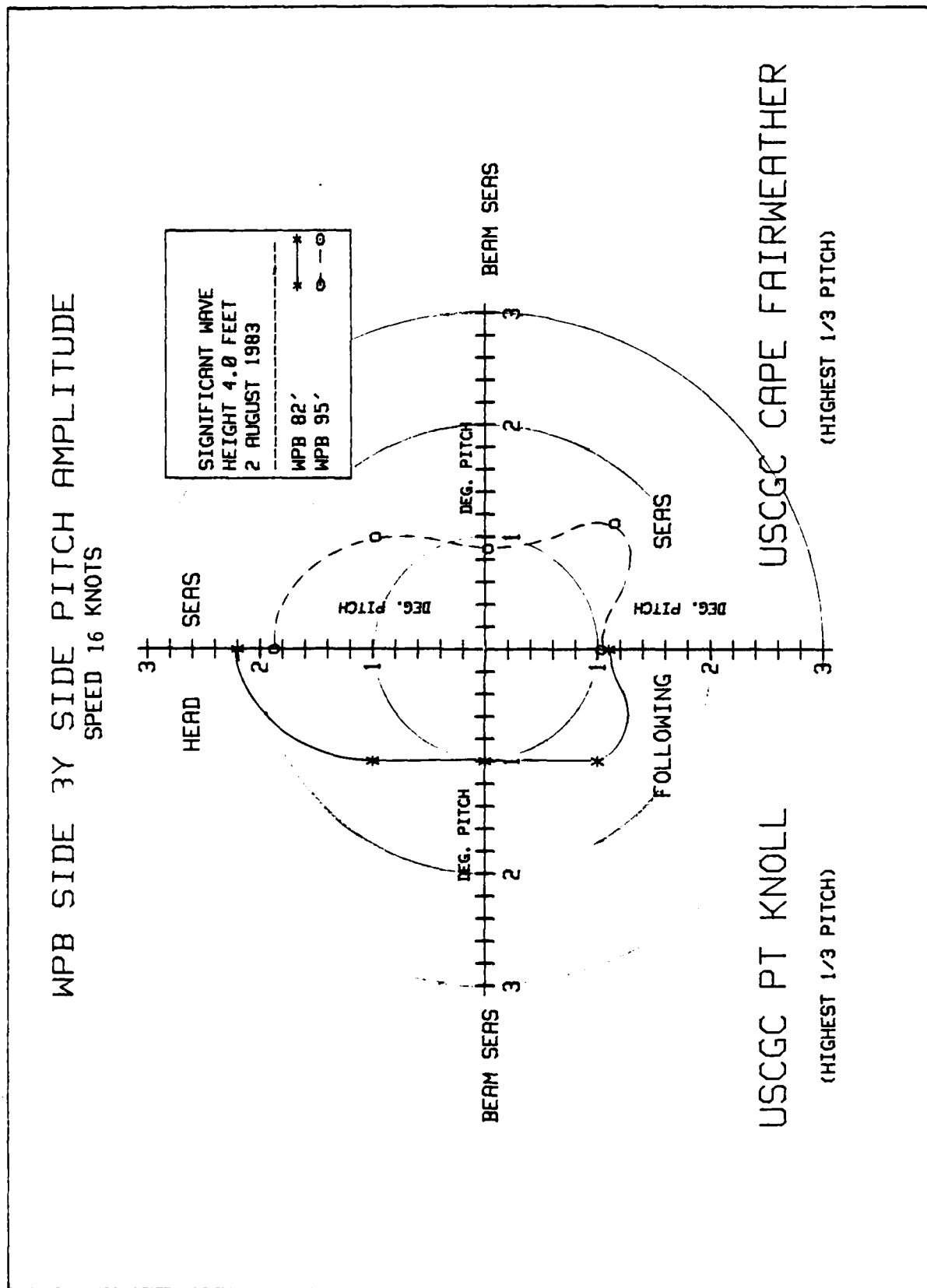


FIGURE 28 - POLAR PLOT - SIDE-BY-SIDE PITCH AMPLITUDE AT 12 KNOTS

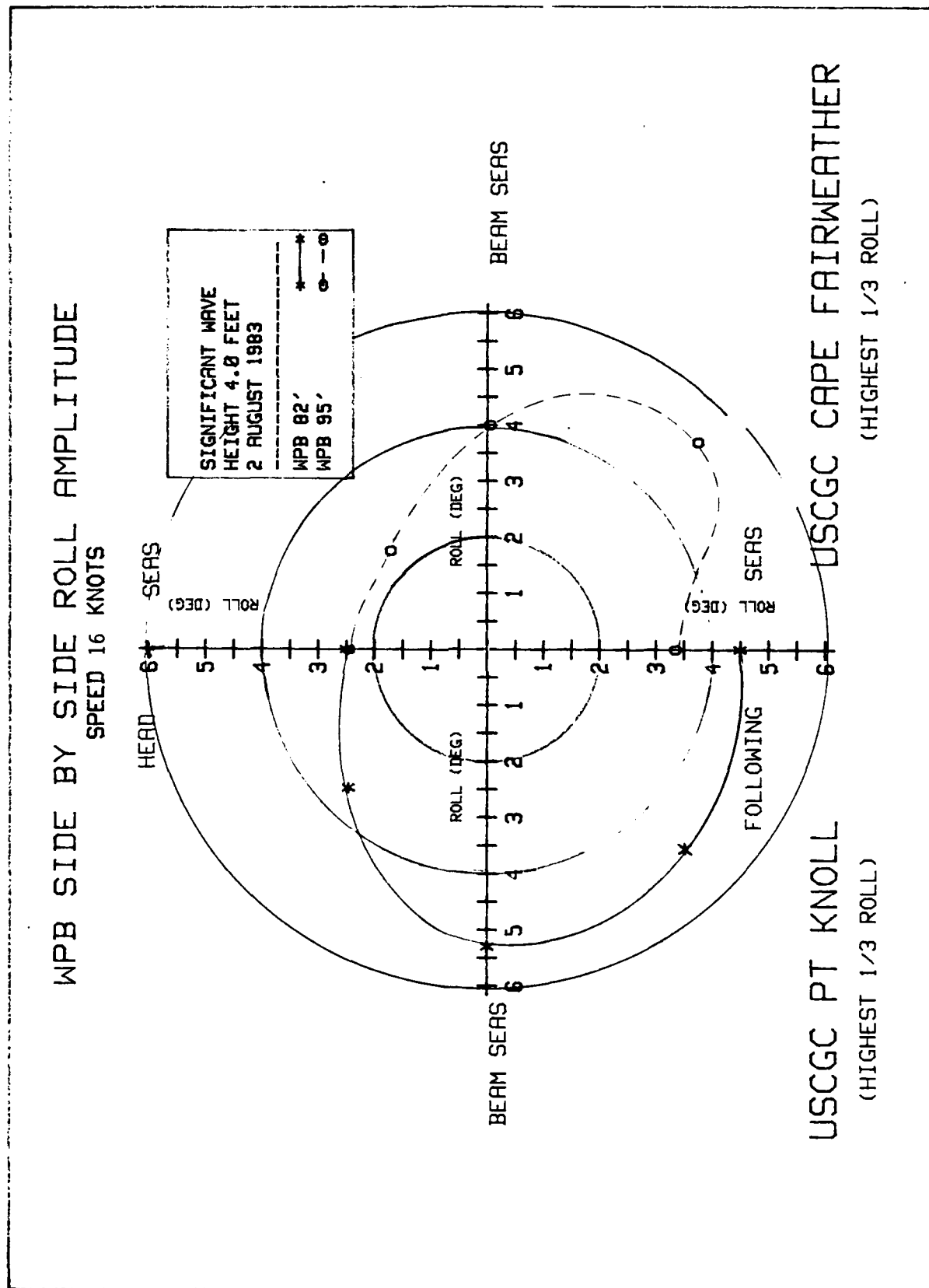


FIGURE 27 - POLAR PLOT - SIDE-BY-SIDE ROLL AMPLITUDE AT 12 KNOTS

TABLE B-III
USCGC CAPE FAIRWEATHER
TACTICAL DATA

Degrees Rudder	Distances in Feet			
	Advance	Transfer	Tactical Diameter	Turning Radius
<u>SPEED 8 KNOTS</u>				
10° Left	950	612	955	250
10° Right	1550	1180	1916	590
20° Left	284	278	594	134
20° Right	266	288	700	172
30° Left	86	116	327	95
30° Right	178	183	315	112
<u>SPEED 12 KNOTS</u>				
10° Left	451	529	992	344
10° Right	420	567	1024	378
20° Left	186	195	467	283
20° Right	323	315	616	207
30° Left	223	251	436	137
30° Right	213	249	492	142
<u>SPEED 18 KNOTS</u>				
10° Left	545	522	992	492
10° Right	630	706	1184	665
20° Left	233	285	570	293
20° Right	493	472	772	301
30° Left	188	161	340	143
30° Right	170	185	443	215

TABLE B-IV

SPIRAL DATA
POINT KNOLL

<u>RUDDER ANGLE</u>	<u>SPEED 6.5 KTS YAW RATE</u>	<u>SPEED 16.5 KTS YAW RATE</u>
<u>Right to Left</u>		
30R	1.71	4.6
20R	.65	2.9
15R	.50	2.3
10R	.07	1.3
5R	-.32	0.4
3R	-.45	-0.3
1R	-.55	-0.6
0	-.64	-0.8
1L	-.79	-0.9
3L	-.77	-1.3
5L	-.94	-1.6
10L	-1.64	-3.0
15L	-1.81	-3.5
20L	-2.44	-4.4
30L	-2.52	-4.9
<u>Left to Right</u>		
30L	-2.52	-4.9
20L	-2.44	-4.4
15L	-1.68	-3.6
10L	-1.66	-2.8
5L	-1.15	-1.9
3L	-.96	-1.5
1L	-.88	-1.0
0	-.80	-0.5
1R	-.58	-0.7
3R	-.43	-0.2
5R	-.36	0.3
10R	+.03	1.4
15R	+.30	2.5
20R	+.69	3.2
30R	+1.71	4.6

TABLE B-V

SPIRAL DATA
CAPE HIGGON

RUDDER ANGLE DEG	SPEED	SPEED
	7.5 KTS YAW RATE DEG/SEC	16 KTS YAW RATE DEG/SEC
<u>Right to Left</u>		
15R	1.77	2.15
10R	1.00	1.24
5R	0.29	0.80
3R	+0.16	0.55
1R	-0.15	0.36
0	-0.50	+0.10
1L	-0.58	-0.17
3L	-0.69	-0.41
5L	-0.83	-0.65
10L	-1.35	-1.39
15L	-1.97	-2.19
<u>Left to Right</u>		
15L	-1.97	-2.19
10L	-1.34	-1.53
5L	-0.88	-1.10
3L	-0.70	-0.71
1L	-0.49	-0.34
0	-0.29	-0.02
1R	-0.08	+0.05
3R	+0.08	0.43
5R	0.70	0.80
10R	1.18	1.50
15R	1.69	1.91

TABLE B-VI
ZIG-ZAG DATA

CAPE FAIRWEATHER

SPEED (KTS)	8	12	17.5
TIME TO SECOND EXECUTE (SEC)	13	16	9
PERIOD (SEC)	64	48	32
AVERAGE OVERSHOOT (DEG)	8.6	6.2	5.8

TABLE B-VII
NOISE LEVEL
USCGC POINT KNOLL
27 July 1983

Operating in calm water, wind speed 5 knots at various ship speeds as indicated.

Compartment or Location	A WEIGHTING (dB)			C WEIGHTING (dB)		
	TWO ENGINES			TWO ENGINES		
	200 SRPM 5.5 Kts	400 SRPM 9.5 Kts	750 SRPM 20 Kts	200 SRPM 5.5 Kts	400 SRPM 9.5 Kts	750 SRPM 20 Kts
Fwd Berthing	58	63	78	64	78	89
CO Stateroom	55	61	71	76	82	85
Bridge	64	71	77	82	94	91
Mess Deck	64	71	82	82.5	88.5	90.5
Back Deck	80	84.5	88.5	94	108	112
Engine room	93	101	111	95	102	111.5

TABLE B-VIII

NOISE LEVEL
USCGC CAPE HIGGON
21 January 1983

Operating in 3-foot swells with 10 knots wind speed at indicated speed and engine configurations.

Compartment or Location	C Weighting dB Level*		
	One Engine (Port) 276 SRPM 10.2 kts	Two Engines 471/450 SRPM 16.0 kts	Two Engines 690/690 SRPM 24.8 kts
Fwd Head	87	88	93
Fwd Berthing	90	86	93
CO Stateroom	89	90	92
Ships Office	86	87	92
Bridge			
(doors closed)	85.5	88	94
Bridge wing	96.5	96	102
Back Deck	90	91	103
Engine Room	107.5	112	117
Mess Deck**	94	97	102-108***
Aft Crew Berthing	90	87.5	102-108***

* "A" weighting of dB levels was not taken due to meter malfunction of that scale. To approximate "A" weighting, subtract 2 dB from C weighting dB levels above.

** Add 1 dB when TV on.

*** Vibrations and noise increased to 108 dB during vibration resonance due to engine/shaft/hull vibrations about once every 2-3 seconds.

TABLE B-IX
WAVE INFORMATION DURING
95'/82' SIDE-BY-SIDE SEAKEEPING TESTS
2 August 1983

SEAS*	H 1/3	Endeco 956 Buoy Avg. Period	Wave Rider Buoy H 1/3
Time 1447 Head Seas Main Wave Direction 1700T	2.8 ft	5.3 sec	3.3 ft
Time 1509 Stern Qtr Seas Main Wave Direction 2000T	2.7 ft	6.0 sec	3.0 ft
Time 1530 Beam Seas Main Wave Direction 1600T	2.8 ft	5.6 sec	3.4 ft
Time 1555 Bow Qtr Seas Main Wave Direction 1700T	2.2 ft	5.3 sec	3.6 ft
Time 1620 Following Seas Main Wave Direction 1400T	2.5 ft	5.5 sec	3.4 ft

*Direction relative to vessels and true direction determined by the Endeco directional buoy.

APPENDIX C
SEAKEEPING PERFORMANCE DATA

TABLE C-I

2 AUGUST 1983
SIDE-BY-SIDE SEAKEEPING
ONE TENTH AND ONE THIRD HIGHEST MOTIONS

SPEED 16 KNOTS
SIGNIFICANT WAVE HEIGHT (H 1/3) 3.0 FT

USCGC POINT KNOLL

Heading Relative to Waves	Roll Angle (Deg) Amplitude		Pitch Angle (Deg) Amplitude		Heave Accel.(G's) Amplitude		Significant* Wave Height H 1/3
	H 1/10	H 1/3	H 1/10	H 1/3	H 1/10	H 1/3	
Head	3.2	2.5	2.7	2.2	0.23	0.18	3.0
Bow Qtr.	4.0	3.5	1.8	1.4	0.16	0.12	2.9
Beam	6.3	5.3	1.3	1.0	0.07	0.05	3.1
Stern Qtr.	8.6	7.1	1.9	1.4	0.11	0.08	2.9
Following	5.7	4.5	1.5	1.1	0.08	0.07	3.0

USCGC CAPE FAIRWEATHER

Heading Relative to Waves	Roll Angle (Deg) Amplitude		Pitch Angle (Deg) Amplitude		Heave Accel (G's)** Amplitude		Significant* Wave Height H 1/3
	H 1/10	H 1/3	H 1/10	H 1/3	H 1/10	H 1/3	
Head	3.1	2.5	2.4	1.9			3.0
Bow Qtr.	3.1	2.5	1.8	1.4			2.9
Beam	5.2	4.0	1.1	0.9			3.1
Stern Qtr.	6.9	5.3	2.0	1.6			2.9
Following	4.3	3.3	1.3	1.0			3.0

* Average of Wave Rider and Endeco 956 buoys for each leg. Wave height measured peak to peak.

** Heave Acceleration data not available due to equipment failure.

TABLE C-II

21 JANUARY 1983

SEAKEEPING

ONE TENTH AND ONE THIRD HIGHEST MOTIONS

SPEED 19.2 KNOTS

ESTIMATED SIGNIFICANT WAVE HEIGHT (H 1/3) 4.0 FT

USCGC CAPE HIGGON

Heading Relative to Waves	Roll Angle (Deg)		Pitch Angle (Deg)		Heave Accel (G's)	
	Amplitude		Amplitude		Amplitude	
	H 1/10	H 1/3	H 1/10	H 1/3	H 1/10	H 1/3
Head	5.9	4.6	2.9	2.4	0.38	0.30
Bow Qtr.	4.7	3.8	3.2	2.6	0.34	0.24
Beam	8.3	6.5	2.3	1.6	0.04	0.03
Stern Qtr.	6.0	4.8	2.6	1.8	0.07	0.06
Following	6.0	4.7	2.3	1.6	0.02	0.02

Drafts	FWD 4'5"	AFT 6'6"
Fuel	FWD 1136 GAL	AFT 1213 GAL
Fresh Water	1228 GAL	
Displacement	110 LT	

APPENDIX D

CALCULATION OF RESPONSE AMPLITUDE OPERATORS (RAOs)

The calculation and use of RAOs assumes certain environmental and response characteristics in order to be valid. The method is only valid for ship responses in an irregular unidirectional seaway only if the responses are linearly proportional to the wave excitation (i.e., the wave amplitude.) In general, any nonlinear ship responses can be ignored in practice; thus, RAO technique for characterization and prediction of ship response are valid as long as a unidirectional sea is available for testing. Ship motions in a confused sea state compared to the motions in the same significant wave height of a unidirectional sea state will be diminished. The Endeco 956 Wave Track buoy provides enough directional information to accurately identify a good unidirectional sea state when available. This was the case during the WPB side-by-side test as seen in the 3-D plot of directional wave energy (Figure 26).

Wave height is measured with a free floating wave buoy, while ship motions are measured by a ship motion package aboard the vessel. A wave spectrum is obtained using a Hewlett-Packard (HP) 5420A digital signal analyzer controlled by an HP 9920S computer utilizing the WAVANL program. A program listing is enclosed in the last section of this appendix.

Next, the wave spectrum is transformed into a spectrum where the frequency of encounter is considered instead of the absolute wave frequency. This conversion is based upon the vessel's speed and direction relative to the major swell direction (i.e., there would be no change for a vessel proceeding in beam seas at any speed.) The area under the modified spectrum is the same as that under the original spectrum, since the total energy remains the same.

Assuming the wave energy is distributed in the form of a Rayleigh distribution, significant wave height is calculated by the formula $H_{1/3} = 4\sqrt{\text{power}}$. This was done as seen in Figure D-1 and a $H_{1/3}$ value of 4.6 feet was determined. This is higher than the wave heights calculated by computer averaging the highest one-third values of the time domain wave records as seen in Table B-IX. This computer averaging method is more accurate than the spectral method and resulted in a 3.3 foot significant wave height. The spectral method was higher (4.6 feet) because it assumes the wave spectrum was a Rayleigh distribution and the actual spectrum was not corrected to fit that distribution. The wave spectrum, however, should not be corrected when used in RAO calculations.

The ship motion record (i.e., roll, pitch, or heave) is also converted to a spectrum. It is already at a frequency of encounter relation because the motions were measured aboard the vessel. The heave spectrum in units of g^2/HZ must be modified to a displacement spectrum (ft^2/HZ) before further calculations can be made. This is performed by integrating the spectrum twice to obtain a displacement spectrum. If a roll or pitch RAO is being calculated, no change is needed because they are already in angular displacement units (deg^2/HZ).

The RAO or transform spectrum is then calculated by dividing the motion amplitude spectrum by the wave amplitude encountered spectrum. This RAO is a non-dimensional representation of the vessel's response to wave encounters. Our analysis stops here, and RAOs, as well as the spectral plots, are presented in Figures D-1 to D-12. Ship motions of the vessel in any other irregular unidirectional seaway can be calculated by multiplying the ordinates of the transformed wave spectrum by the ordinates of the RAO for the corresponding frequencies of encounters. The tabular data for all spectra shown in Figures D-1 to D-12 is listed in Tables D-I to D-XII.

Finally, the area under the motion amplitude spectrum is determined in order to obtain the necessary motion characteristics (i.e., average, $H_{1/3}$, $H_{1/10}$ motion amplitudes.) This assumes a Rayleigh distribution of the motions.

A problem arises when obtaining RAOs from full-scale ship data if there is little or no wave energy at a given frequency, but for some reason there is a small amount of motion energy. This happened on several plots in this investigation at the low frequency range, below 0.1 HZ frequency of encounter for roll and pitch RAO's. What happens is that a small value of motion amplitude is divided by a very small wave encounter amplitude value, resulting in a large erroneous peak value on the RAO plot. These low frequency peaks as seen in Figures D-6, D-8, and D-12 seem to be large resonant peaks; however, they are not significant and are very misleading.

If the RAOs are to be used to predict motions in a realistic seaway, little harm will be caused since the wave encounter spectra likely to be used will have little or no energy in that very low frequency range. Thus the resulting motion spectra will not have erroneous peaks at low frequencies. It is recommended, however, that the RAOs be used with caution when calculating ship motions and information below 0.1 HZ should be ignored. Under no circumstances should these RAOs be used to predict motions in very low frequencies below 0.1 HZ (encountered frequency.)

2 AUGUST 1983

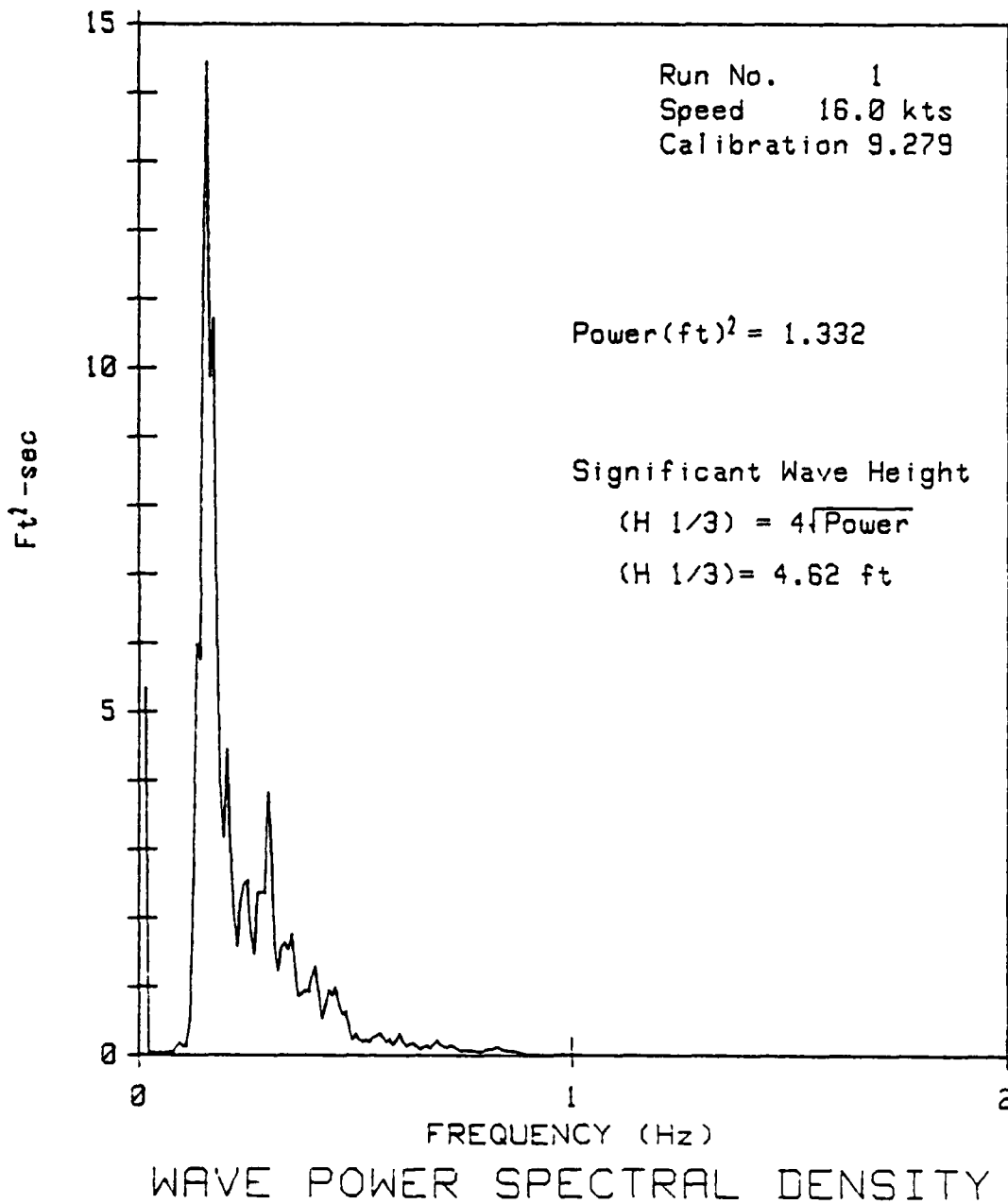


FIGURE D-1. WAVE SPECTRUM DURING SIDE-BY-SIDE TESTING

Tested 2 AUGUST 1983

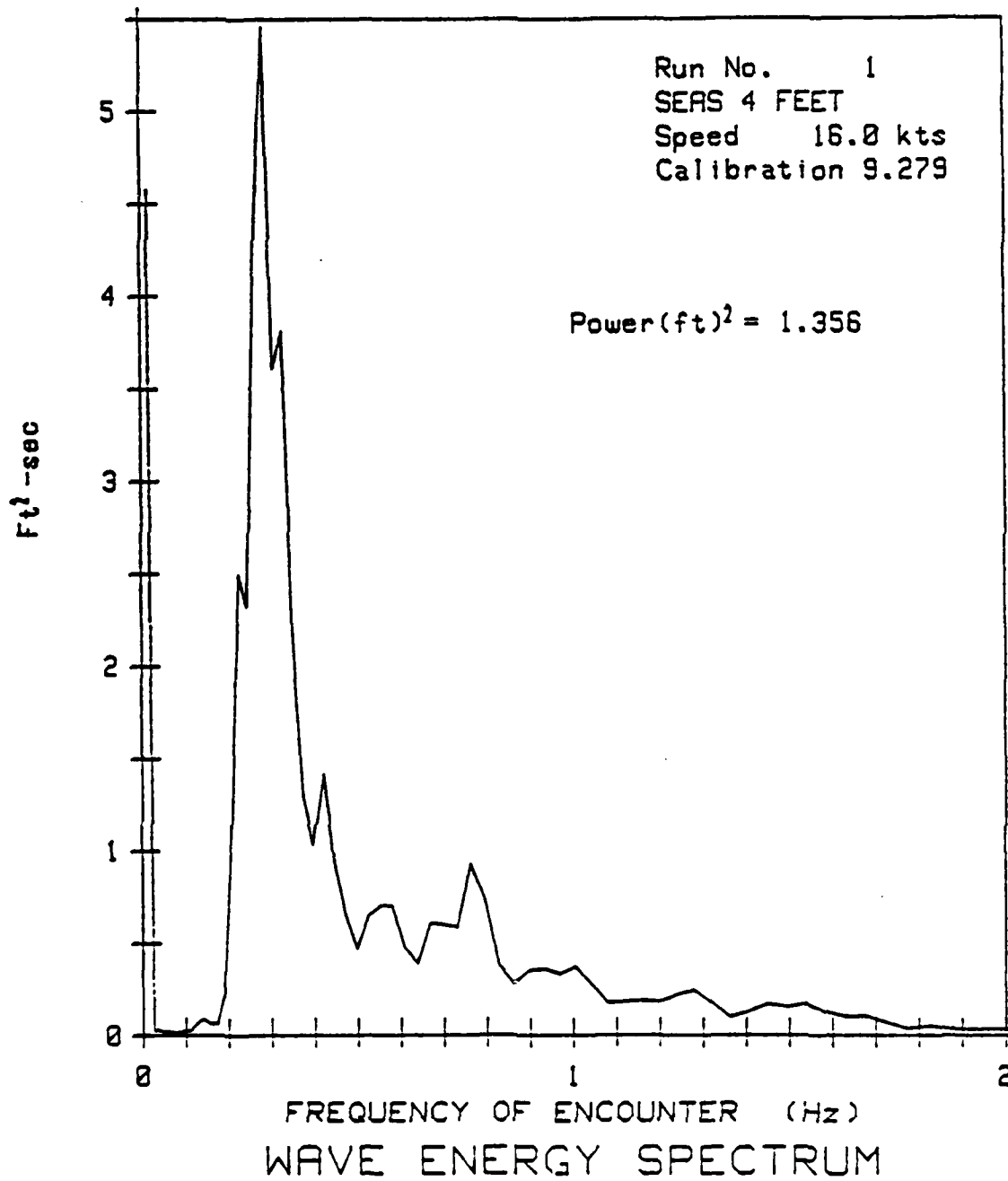


FIGURE D-2. TRANSFORMED WAVE SPECTRUM

TABLE D-IV

POINT KNOLL HEAVE RAO

USCGC PT KNOLL (HEAD SEAS)

HEAVE Response Amplitude Operator
Tested 2 August 1983

Run No. 1, Speed 16, SEAS Seas about 4 feet

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE RAO
.015625	1.435219E+00
.023438	7.260151E-05
.031250	1.425045E-03
.054688	1.768781E-04
.078125	6.021988E-04
.109375	1.987568E-03
.156250	3.247658E-03
.171875	7.323262E-03
.179688	5.487395E-03
.187500	7.688353E-03
.195313	3.696779E-03
.210938	4.319904E-03
.226563	1.657279E-03
.234375	2.783973E-03
.242188	4.057267E-03
.250000	2.854767E-03
.257813	3.953469E-03
.273438	3.020403E-03
.296875	3.439611E-03
.312500	2.878056E-03
.328125	6.620081E-03
.335938	5.880697E-03
.359375	1.242885E-02
.367188	9.739944E-03
.390625	1.844997E-02
.398438	1.195158E-02
.406250	1.469302E-02
.421875	4.617869E-03
.437500	6.892307E-03
.453125	5.368095E-03
.460938	7.543900E-03
.468750	6.576043E-03
.484375	4.798464E-03
.492188	5.203912E-03
.507813	2.863617E-03
.515625	3.209282E-03
.523438	2.352046E-03
.531250	2.371794E-03
.546875	1.405306E-03
.617188	2.448836E-04
.625000	4.351193E-04
.703125	2.584862E-05
.791250	1.095222E-05
.859375	5.484931E-05
.937500	3.631421E-05
1.015625	2.673759E-05
1.093750	2.180420E-05
1.171875	1.293541E-05
1.250000	4.217825E-06
1.323125	6.419185E-06

TABLE D-III

POINT KNOLL HEAVE DISPLACEMENT PSD

USCGC PT KNOLL (HEAD SEAS)

HEAVE Energy Spectrum
Tested 2 August 1983

Run No. 1, Speed 16, SEAS Seas about 4 feet

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE (DEG SQR-SEC)
.023438	1.034504E-04
.078125	1.054833E-05
.156250	2.017503E-04
.210938	5.845034E-03
.226563	4.125868E-03
.234375	6.730119E-03
.242188	9.515748E-03
.250000	8.202895E-03
.265625	1.495153E-02
.273438	1.477622E-02
.289063	1.672593E-02
.312500	1.056402E-02
.328125	2.500092E-02
.335938	1.886244E-02
.351563	2.459306E-02
.367188	1.484687E-02
.382813	2.044768E-02
.390625	2.031173E-02
.398438	1.272541E-02
.406250	1.746668E-02
.421875	6.444415E-03
.429688	7.853438E-03
.453125	4.595069E-03
.460938	5.788411E-03
.468750	4.462486E-03
.507813	1.542769E-03
.546875	9.754100E-04
.617188	1.096917E-04
.625000	1.849294E-04
.703125	1.539015E-05
.791250	8.922808E-06
.859375	1.565613E-05
.937500	1.289267E-05
1.015625	9.188409E-06
1.093750	3.880714E-06
1.171875	2.380350E-06
1.250000	9.645831E-07
1.328125	1.016320E-06
1.406250	3.777297E-07
1.484375	2.407388E-07
1.562500	1.737458E-07
1.640625	1.783904E-07
1.718750	1.380254E-07
1.796875	8.131315E-08
1.875000	7.115200E-08
1.953125	3.959869E-08

TABLE D-II
TRANSFORMED WAVE SPECTRUM

Wave Power Spectral Density
Tested 2 AUGUST 1983

Run No. 1
FREQUENCY

(HERTZ)

AMPLITUDE

(FT SQR-SEC)

.015625	5.331787E+00
.023438	3.167915E-02
.078125	4.718971E-02
.132813	5.992920E+00
.140625	5.761474E+00
.156250	1.445019E+01
.164063	9.856936E+00
.171875	1.071924E+01
.195313	3.162354E+00
.203125	4.456054E+00
.226563	1.582825E+00
.234375	2.252808E+00
.250000	2.536743E+00
.265625	1.474182E+00
.281250	2.369751E+00
.289063	2.363159E+00
.296875	3.834594E+00
.312500	1.625122E+00
.320313	1.224610E+00
.335938	1.637024E+00
.343750	1.530457E+00
.351563	1.762390E+00
.367188	8.528440E-01
.390625	9.262088E-01
.468750	5.994262E-01
.546875	2.885894E-01
.625000	1.684723E-01
.648438	8.694840E-02
.703125	1.234665E-01
.781250	5.677223E-02
.859375	6.491089E-02
.937500	1.330423E-02

TABLE D-I
SIDE-BY-SIDE WAVE PSD

USCGC CAPE FAIRWEATHER &
USCGC PT KNOLL (HEAD SEAS)

Wave Energy Spectrum
Tested 2 AUGUST 1983

Run No. 1, Speed 16 , SEAS 4 FEET

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE (DEG SQR-SEC)
.016912	4.577476E+00
.026334	2.540060E-02
.110310	2.587243E-02
.225827	2.496327E+00
.244905	2.320285E+00
.284990	5.457276E+00
.305999	3.610242E+00
.327651	3.811063E+00
.396469	1.033501E+00
.420696	1.418114E+00
.497239	4.669897E-01
.524041	6.488848E-01
.551486	7.032197E-01
.637685	3.878009E-01
.667705	6.087511E-01
.729676	5.837020E-01
.761628	9.282562E-01
.827461	3.783091E-01
.861344	2.797096E-01
1.195252	1.809111E-01
1.627413	1.008519E-01
2.123944	4.264301E-02

USCGC CAPE FAIRWEATHER (BEAM SEAS)

Tested 2 August 1983

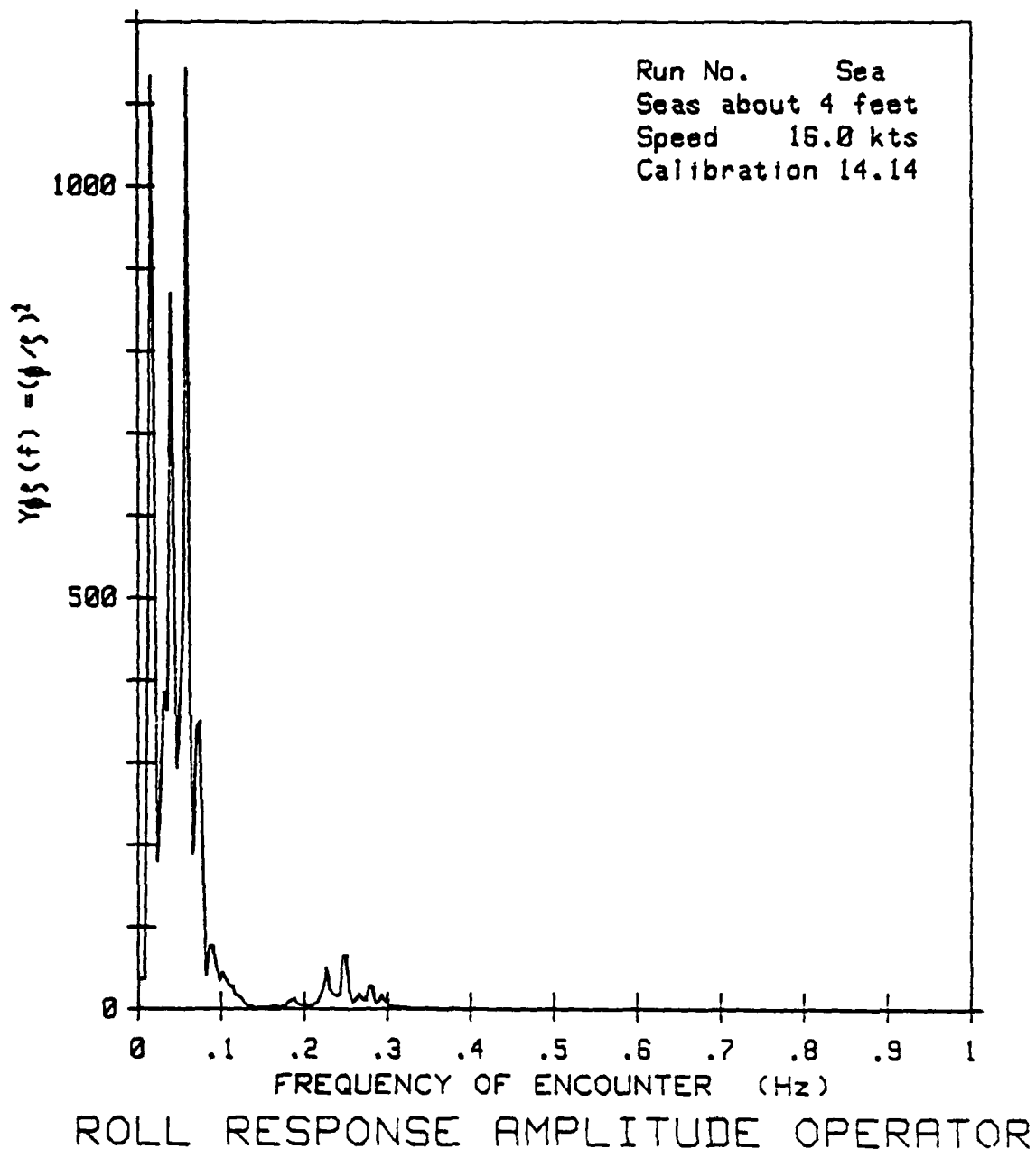


FIGURE D-12. CAPE FAIRWEATHER ROLL RAO

USCGC CAPE FAIRWEATHER (BEAM SEAS)

Tested 2 August 1983

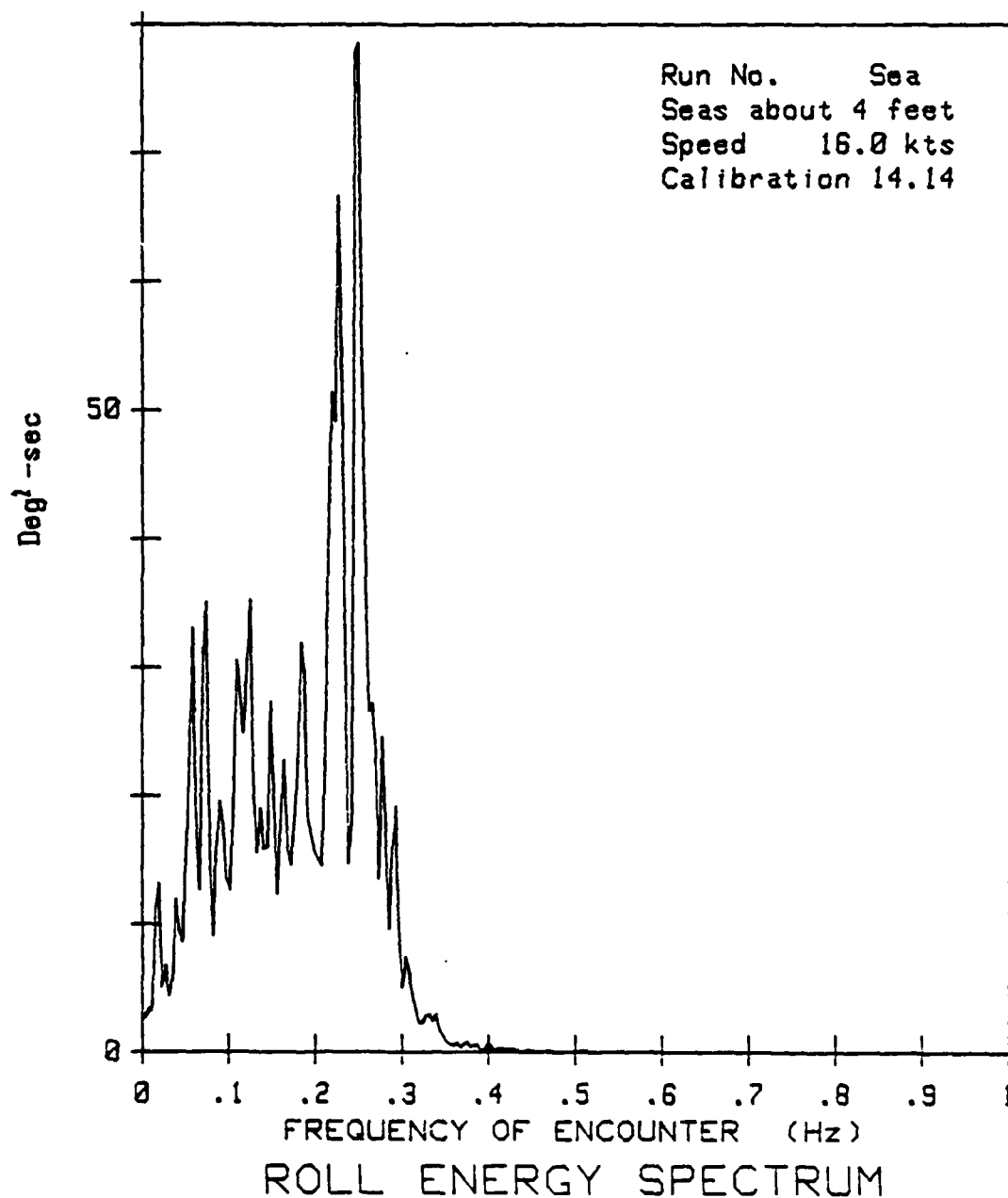


FIGURE D-11. CAPE FAIRWEATHER ROLL PSD

USCGC CAPE FAIRWEATHER (HEAD SEAS)

Tested 2 August 1983

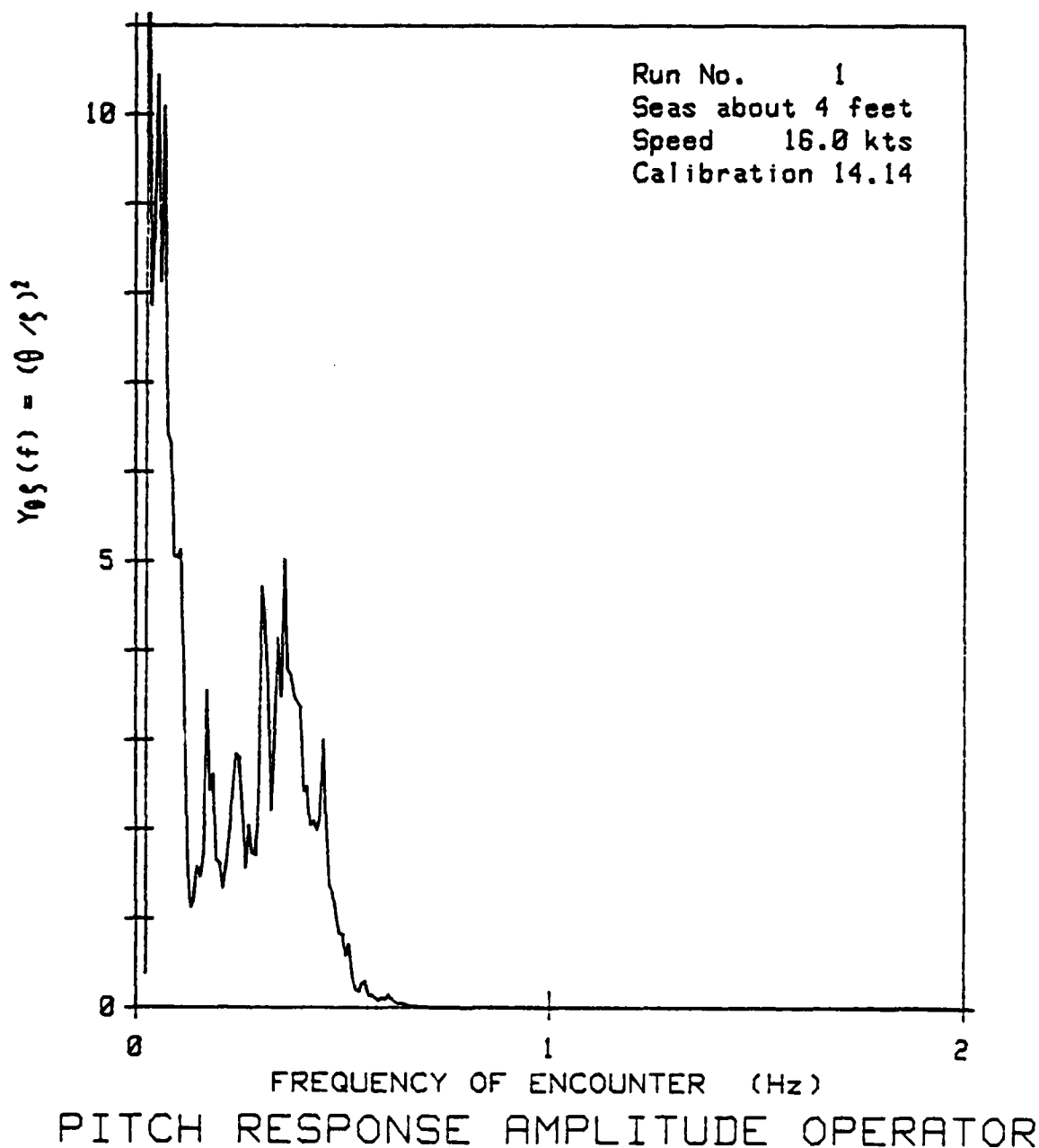


FIGURE D-10. CAPE FAIRWEATHER PITCH RAO

USCGC CAPE FAIRWEATHER (HEAD SEAS)

Tested 2 August 1983

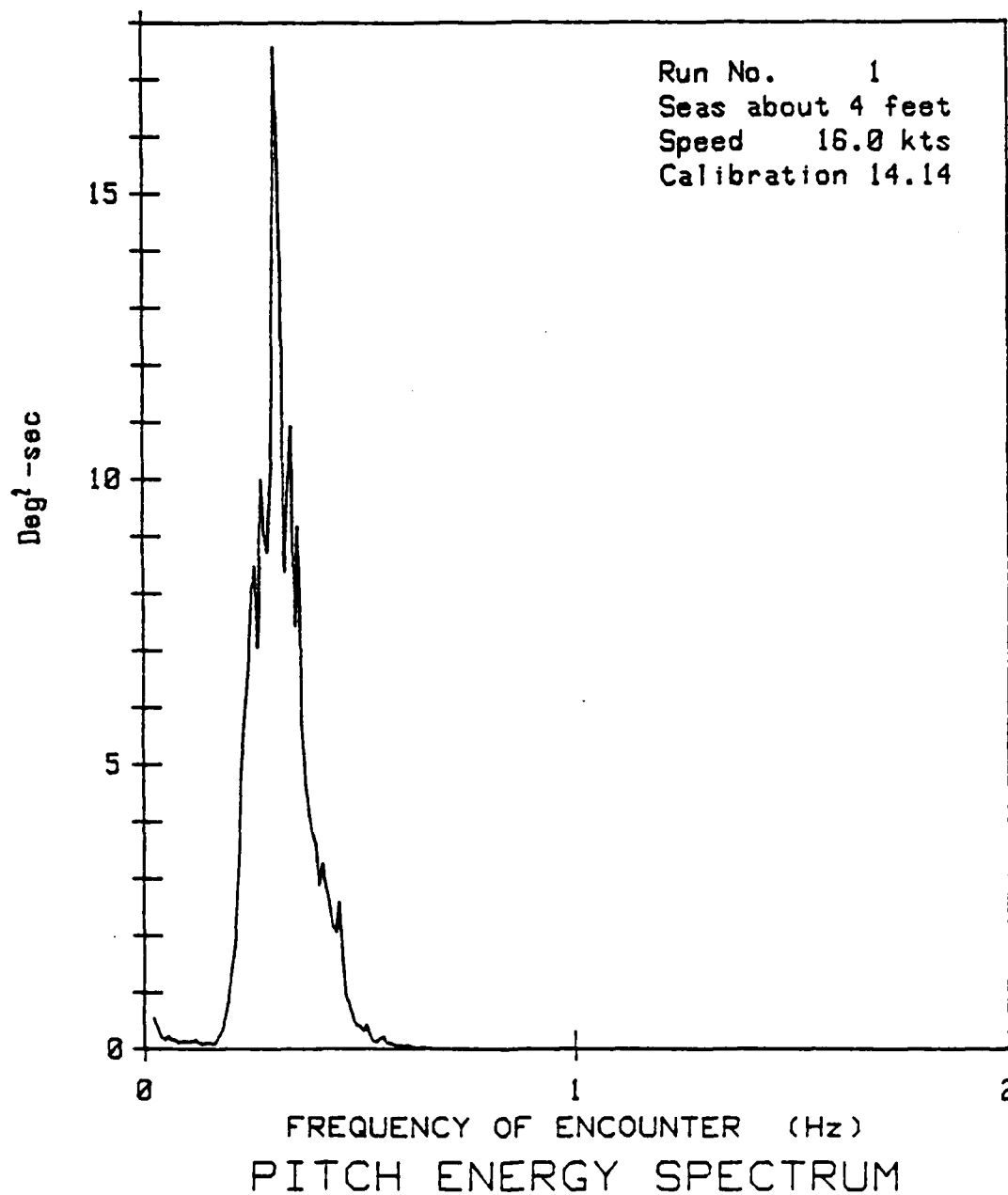


FIGURE D-9. CAPE FAIRWEATHER PITCH PSD

USCGC PT KNOLL (BEAM SEAS)

Tested 2 August 1983

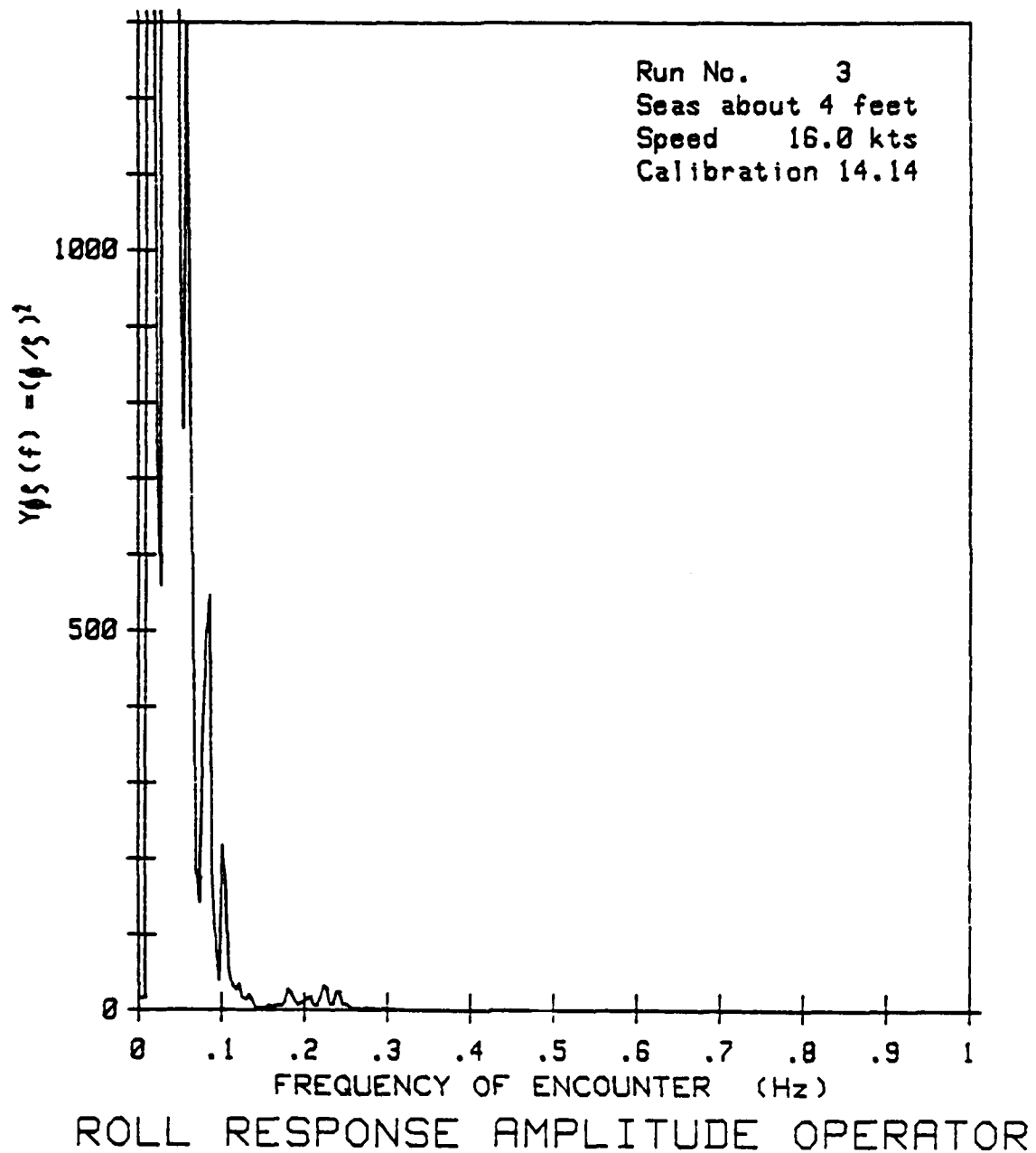


FIGURE D-8. POINT KNOLL ROLL RAO

USCGC PT KNOLL (BEAM SEAS)

Tested 2 August 1983

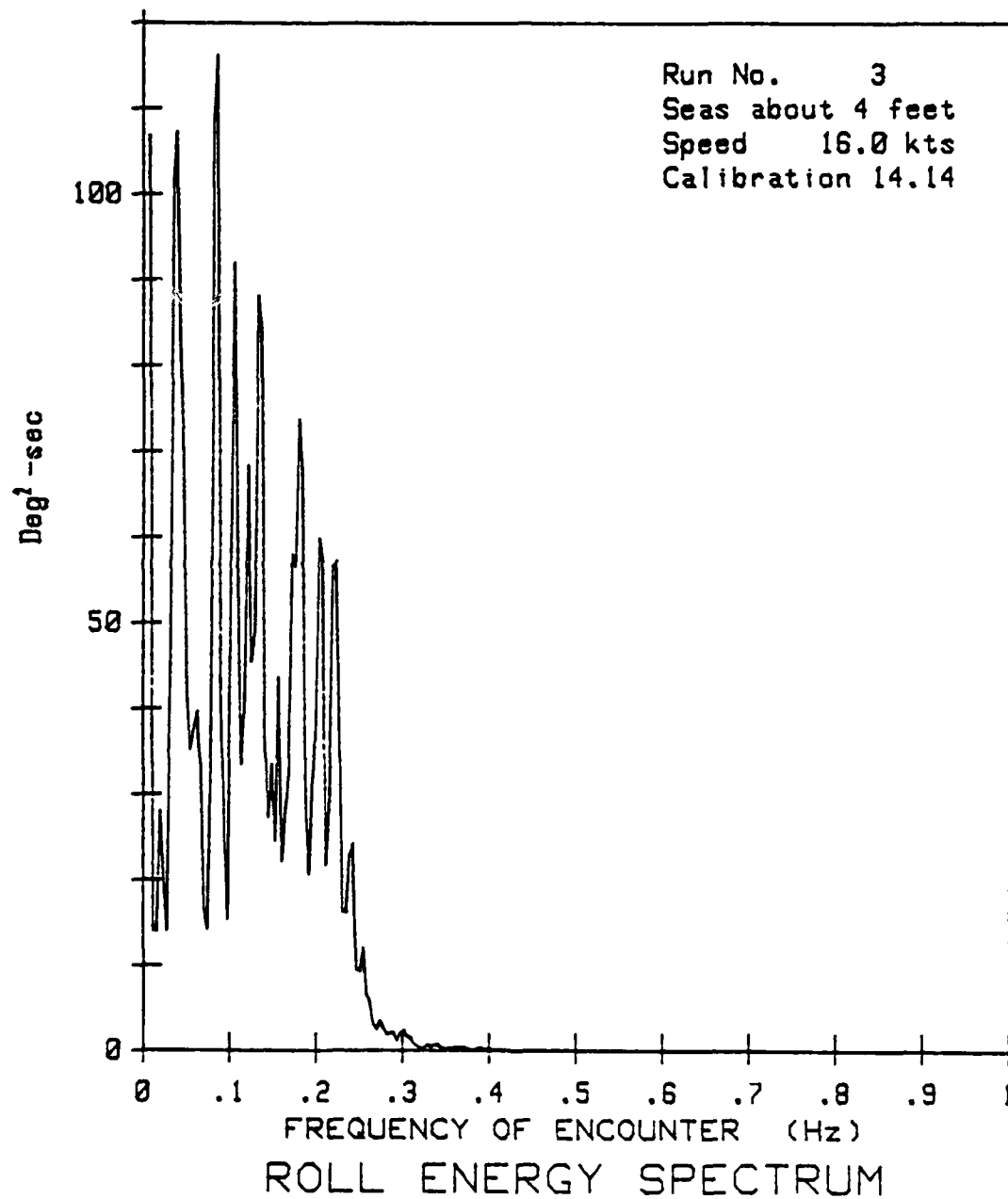


FIGURE D-7. POINT KNOLL ROLL PSD

USCGC PT KNOLL (HEAD SEAS)

Tested 2 August 1983

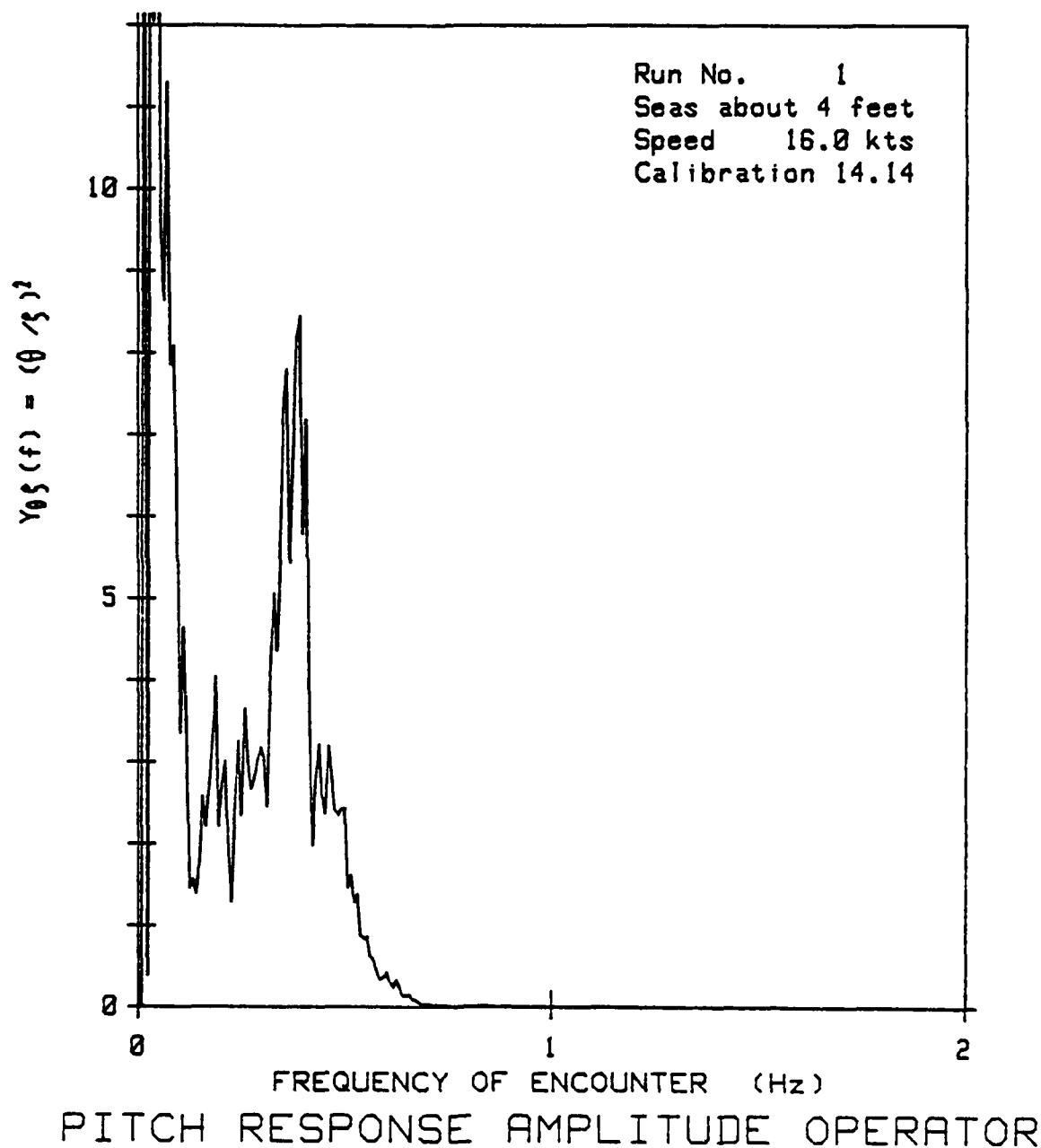


FIGURE D-6. POINT KNOLL PITCH RAO

USCGC PT KNOLL (HEAD SEAS)

Tested 2 August 1983

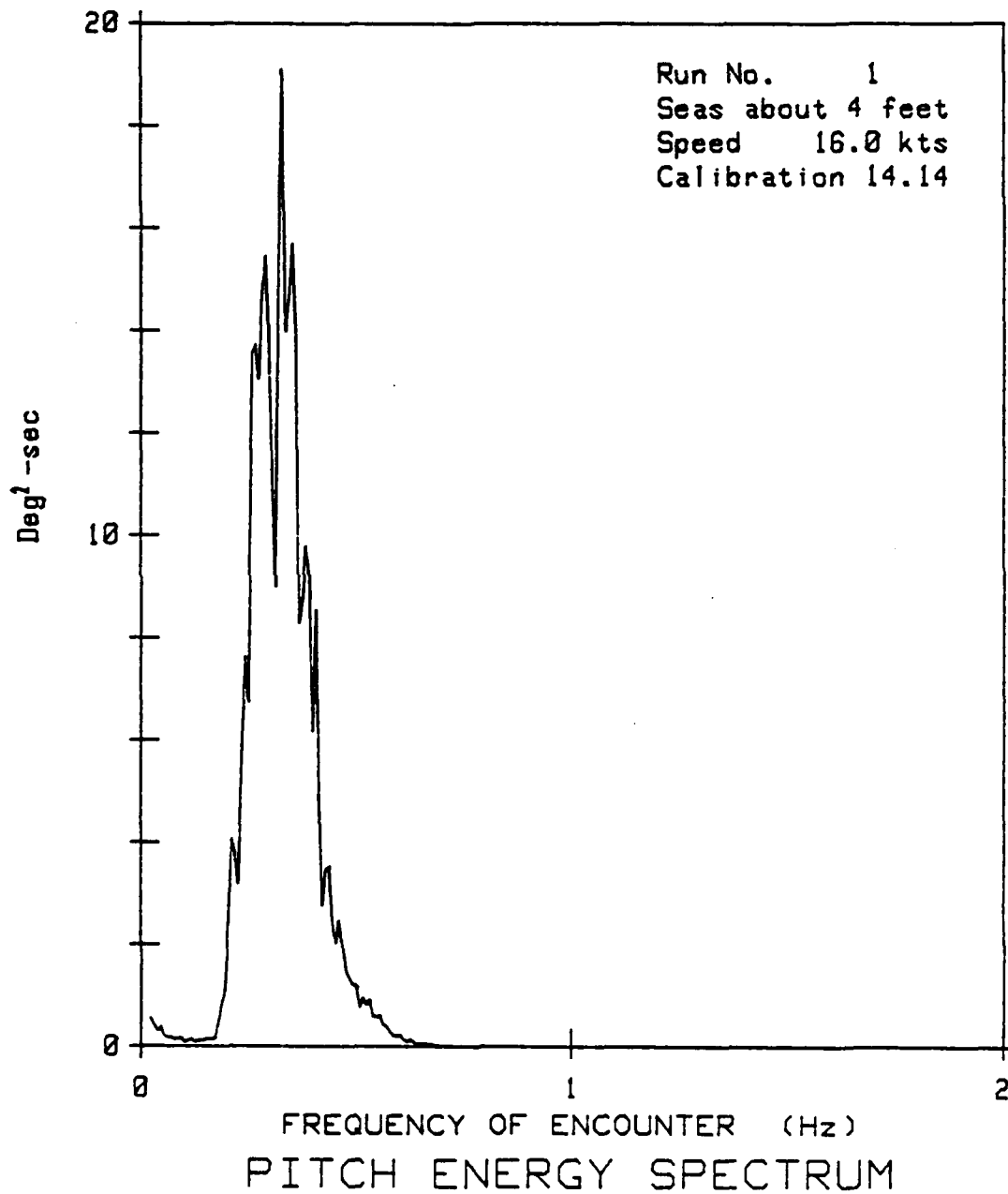


FIGURE D-5. POINT KNOLL PITCH PSD

USCGC PT KNOLL (HEAD SEAS)

Tested 2 August 1983

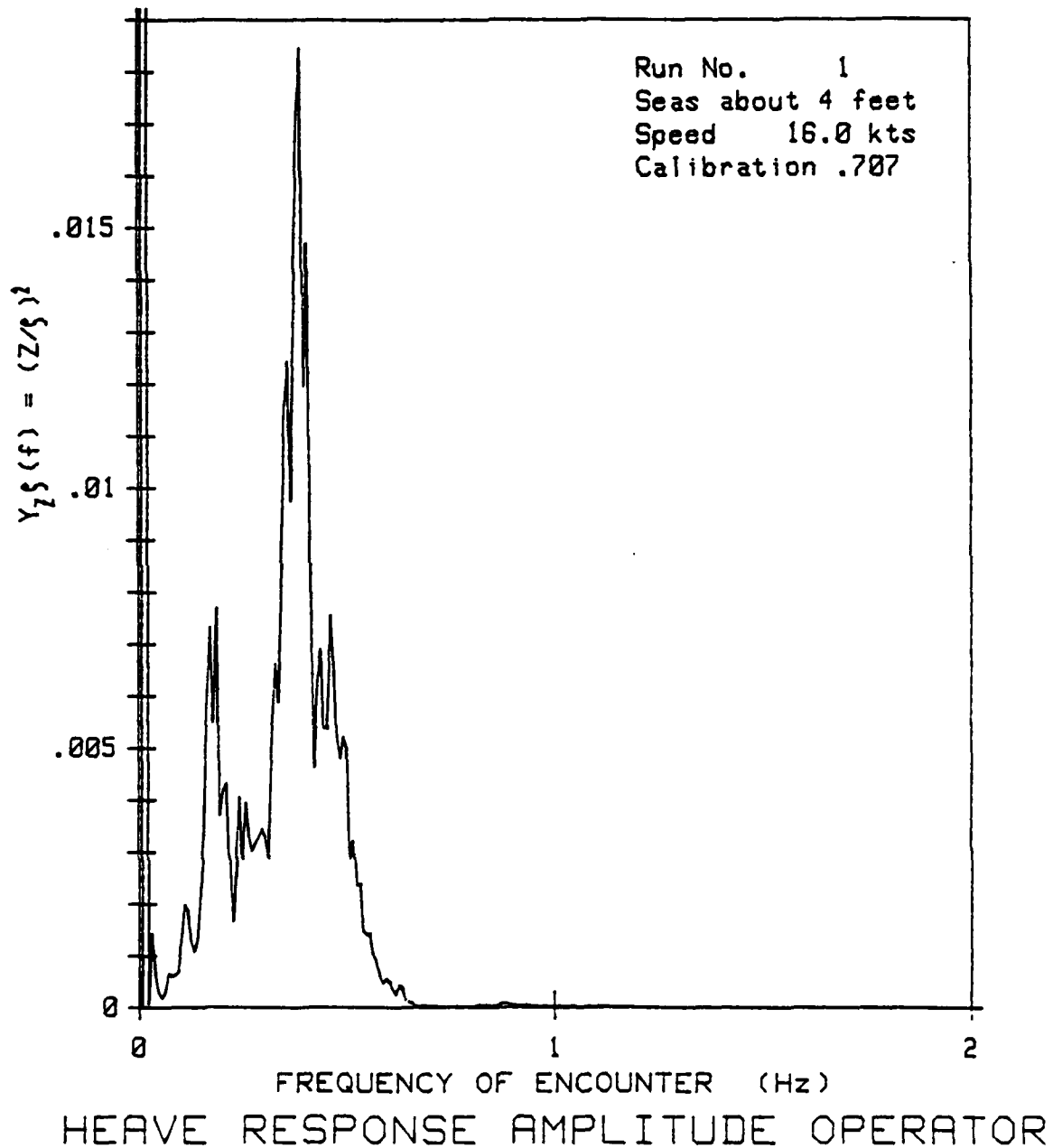


FIGURE D-4. POINT KNOLL HEAVE RAO

USCGC PT KNOLL (HEAD SEAS)

Tested 2 August 1983

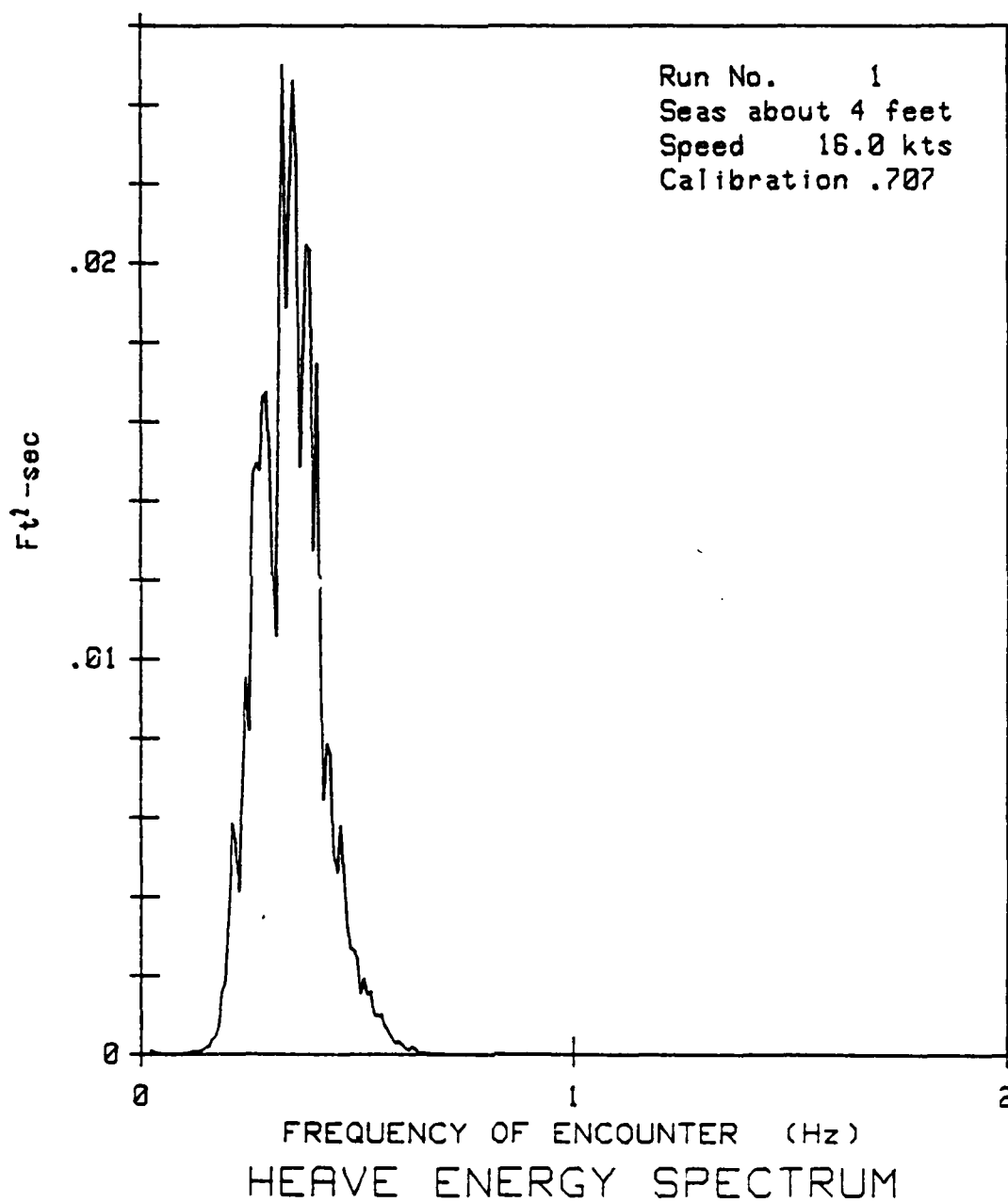


FIGURE D-3. POINT KNOLL HEAVE DISPLACEMENT PSD

TABLE D-V
POINT KNOLL PITCH PSD

USCGC PT KNOLL (HEAD SEAS)

PITCH Energy Spectrum
Tested 2 August 1983

Run No. 1, Speed 16 , SEAS Seas about 4 feet

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE (DEG SQR-SEC)
.023438	5.506592E-01
.078125	1.374588E-01
.156250	1.604386E-01
.210938	4.066894E+00
.226563	3.184326E+00
.234375	5.873047E+00
.242188	7.628906E+00
.250000	6.738526E+00
.265625	1.372607E+01
.273438	1.304443E+01
.289063	1.544873E+01
.312500	8.989256E+00
.328125	1.909570E+01
.335938	1.397070E+01
.351563	1.568554E+01
.367188	8.281736E+00
.382813	9.779784E+00
.390625	9.288576E+00
.398438	6.158691E+00
.406250	8.538088E+00
.421875	2.756470E+00
.437500	3.522705E+00
.453125	2.025634E+00
.460938	2.454346E+00
.468750	1.926330E+00
.507813	7.831116E-01
.546875	5.829468E-01
.625000	1.414947E-01
.703125	1.995466E-02
.781250	5.923271E-03
.859375	3.879428E-03
.937500	3.086567E-03
1.015625	3.048182E-03
1.093750	1.057923E-03
1.171875	7.369220E-04
1.250000	3.295242E-04
1.328125	2.738982E-04
1.406250	1.288056E-04
1.484375	1.306236E-04
1.562500	5.522370E-05
1.640625	1.040250E-04
1.718750	1.276806E-04
1.796875	9.977072E-05
1.875000	1.029037E-04
1.953125	9.327384E-05

TABLE D-VI

POINT KNOLL PITCH RAO

USCGC PT KNOLL (HEAD SEAS)

PITCH Response Amplitude Operator
Tested 2 August 1983

Run No. 1, Speed 16 , SEAS Seas about 4 feet

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE RAO
.015625	1.640386E+01
.023438	3.864528E-01
.031250	1.547483E+01
.039063	1.204820E+01
.046875	2.039915E+01
.062500	8.637983E+00
.070313	1.130644E+01
.078125	7.847452E+00
.085938	8.083470E+00
.101563	3.343719E+00
.109375	4.642467E+00
.125000	1.449216E+00
.132813	1.566039E+00
.140625	1.393958E+00
.156250	2.582646E+00
.164063	2.215597E+00
.187500	4.039941E+00
.195313	2.209781E+00
.210938	3.005730E+00
.226563	1.279080E+00
.234375	2.429438E+00
.242188	3.252767E+00
.250000	2.345138E+00
.257813	3.645694E+00
.273438	2.666409E+00
.296875	3.176313E+00
.312500	2.449028E+00
.328125	5.056419E+00
.335938	4.355613E+00
.359375	7.794865E+00
.367188	5.432310E+00
.390625	8.437191E+00
.398438	5.784182E+00
.406250	7.182263E+00
.421875	1.975201E+00
.437500	3.213271E+00
.453125	2.366406E+00
.460938	3.198691E+00
.468750	2.838694E+00
.484375	2.354718E+00
.500000	2.428578E+00
.507813	1.453576E+00
.515625	1.612905E+00
.523438	1.277895E+00
.531250	1.375542E+00
.546875	8.398712E-01
.585938	3.296985E-01
.625000	3.329221E-01
.703125	3.351501E-02
.781250	7.270464E-03

TABLE D-VII
POINT KNOLL ROLL PSD

USCGC PT KNOLL (BEAM SEAS)

ROLL Energy Spectrum
Tested 2 August 1983

Run No. 1, Speed 16, SEAS Seas about 4 feet

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE (DEG SQR-SEC)
.007813	1.068203E+02
.011719	1.397266E+01
.019531	2.810156E+01
.027344	1.401416E+01
.039063	1.072617E+02
.054688	3.518164E+01
.062500	3.963086E+01
.074219	1.415918E+01
.078125	3.584375E+01
.085938	1.161718E+02
.097656	1.532129E+01
.105469	9.195312E+01
.113281	3.341992E+01
.117188	4.048633E+01
.121094	6.830469E+01
.125000	4.537695E+01
.132813	8.813672E+01
.144531	2.720801E+01
.148438	3.349610E+01
.152344	2.449023E+01
.156250	4.360938E+01
.160156	2.207617E+01
.171875	5.797656E+01
.175781	5.653125E+01
.179688	7.371875E+01
.191406	2.051172E+01
.195313	3.211914E+01
.203125	5.984375E+01
.210938	2.163086E+01
.222656	5.709570E+01
.234375	1.613183E+01
.242188	2.419336E+01
.250000	9.215328E+00
.269531	2.494018E+00
.273438	3.477783E+00
.312500	7.980957E-01
.351563	2.773742E-01
.390625	3.113403E-01
.429688	3.044056E-02
.468750	2.820301E-02
.507813	5.341148E-02
.546875	4.767799E-02
.585938	4.184150E-02
.625000	5.363655E-02
.664063	4.553795E-02

TABLE D-VIII
POINT KNOLL ROLL RAO

USCGC PT KNOLL (BEAM SEAS)

ROLL Response Amplitude Operator
Tested 2 August 1983

Run No. 1, Speed 16 , SEAS Seas about 4 feet

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE RAO
.011719	1.672247E+03
.015625	1.409681E+03
.019531	1.557432E+03
.027344	5.588056E+02
.039063	7.830403E+03
.054688	7.653021E+02
.058594	1.299493E+03
.074219	1.414483E+02
.078125	3.831285E+02
.085938	5.465301E+02
.097656	3.925624E+01
.101563	2.173406E+02
.117188	2.758350E+01
.156250	6.671049E+00
.195313	9.687420E+00
.234375	8.715138E+00
.273438	2.814383E+00
.312500	5.488121E-01
.351563	2.039904E-01
.390625	1.538114E-01
.429688	1.306830E-01
.468750	1.138299E-01
.507813	1.359422E-01
.546875	3.493153E-01
.585938	2.199683E-01
.625000	3.696240E-01
.664063	3.102906E-01
.703125	1.859956E-01
.742188	1.679121E-01
.781250	8.719267E-02
.820313	1.057532E-01
.859375	6.767849E-02
.898438	2.859334E-02
.937500	4.219100E-02
.976563	1.874125E-01

TABLE D-IX
CAPE FAIRWEATHER PITCH PSD

USCGC CAPE FAIRWEATHER (HEAD SEAS)

PITCH Energy Spectrum
Tested 2 August 1983

Run No. 1, Speed 16 , SEAS Seas about 4 feet

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE (DEG SQR-SEC)
.023438	5.422363E-01
.078125	1.126404E-01
.156250	9.160232E-02
.234375	5.837402E+00
.257813	8.475096E+00
.265625	7.048096E+00
.273438	9.994144E+00
.289063	8.722168E+00
.304688	1.755957E+01
.312500	1.581787E+01
.328125	8.365720E+00
.343750	1.091943E+01
.351563	7.407715E+00
.359375	9.160648E+00
.390625	3.760986E+00
.406250	2.875854E+00
.414063	3.252686E+00
.445313	2.039917E+00
.453125	2.574707E+00
.468750	9.339296E-01
.507813	3.145446E-01
.546875	1.901932E-01
.625000	2.920818E-02
.703125	3.855467E-03
.781250	3.644705E-03
.859375	3.317237E-03
.937500	1.894653E-03
1.015625	1.884401E-03
1.093750	6.698370E-04
1.171875	7.992089E-04
1.250000	6.879270E-04
1.328125	4.772097E-04
1.406250	4.674942E-04
1.484375	7.528961E-04
1.562500	3.689677E-04
1.640625	6.748438E-04
1.718750	2.972484E-04
1.796875	3.932714E-04
1.875000	5.038082E-04
1.953125	6.151498E-04

TABLE D-X

CAPE FAIRWEATHER PITCH RAO

USCGC CAPE FAIRWEATHER (HEAD SEAS)

PITCH Response Amplitude Operator
Tested 2 August 1983

Run No. 1, Speed 16 , SEAS Seas about 4 feet

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE RAO
.031250	1.351635E+01
.039063	7.861338E+00
.054688	1.044136E+01
.062500	8.125118E+00
.070313	1.009137E+01
.078125	6.430582E+00
.101563	5.039529E+00
.109375	5.125665E+00
.132813	1.122625E+00
.148438	1.584508E+00
.156250	1.474560E+00
.171875	3.550550E+00
.179688	2.433715E+00
.187500	2.614670E+00
.210938	1.342456E+00
.234375	2.414693E+00
.242188	2.843360E+00
.265625	1.562783E+00
.273438	2.042900E+00
.289063	1.710479E+00
.304688	4.713314E+00
.312500	4.309412E+00
.328125	2.215189E+00
.343750	4.138490E+00
.351563	3.485853E+00
.359375	5.020065E+00
.390625	3.416257E+00
.406250	2.419176E+00
.414063	2.477668E+00
.421875	2.044392E+00
.429688	2.088754E+00
.437500	1.987334E+00
.453125	3.007849E+00
.468750	1.376265E+00
.507813	5.038434E-01
.546875	2.740178E-01
.625000	6.872376E-02
.679688	1.157198E-02
.703125	6.475475E-03
.731250	4.473659E-03
.859375	1.162153E-02
.937500	5.336583E-03
1.015625	5.483467E-03

TABLE D-XI

CAPE FAIRWEATHER ROLL PSD

USCGC CAPE FAIRWEATHER (BEAM SEAS)

ROLL Energy Spectrum
Tested 2 August 1983

Run No. Seas about 4 feet, Speed 16 , SEAS Seas about 4 feet

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE (DEG SQR-SEC)
.019531	1.322314E+01
.023438	5.035889E+00
.039063	1.193115E+01
.046875	8.593264E+00
.058594	3.310547E+01
.066406	1.263623E+01
.074219	3.505664E+01
.078125	1.686914E+01
.082031	9.024904E+00
.089844	1.955371E+01
.101563	1.267920E+01
.109375	3.053027E+01
.117188	2.489453E+01
.125000	3.518164E+01
.132813	1.551416E+01
.136719	1.897558E+01
.140625	1.583350E+01
.148438	2.730859E+01
.156250	1.230762E+01
.164063	2.272656E+01
.171875	1.460791E+01
.183594	3.185156E+01
.195313	1.680469E+01
.207031	1.453222E+01
.218750	5.140234E+01
.222656	4.909570E+01
.226563	6.657422E+01
.234375	3.296875E+01
.238281	1.460994E+01
.250000	7.851172E+01
.261719	2.649902E+01
.265625	2.712988E+01
.273438	1.347363E+01
.277344	2.452539E+01
.285156	9.585448E+00
.292969	1.913574E+01
.300781	5.043457E+00
.312500	4.532715E+00
.351563	8.107296E-01
.359375	5.762024E-01
.390625	1.964188E-01
.429688	2.253799E-01
.468750	1.077462E-01
.507813	1.348318E-01
.546875	1.342010E-02

TABLE D-XII

CAPE FAIRWEATHER ROLL RAO

USCGC CAPE FAIRWEATHER (BEAM SEAS)

ROLL Response Amplitude Operator
 Tested 2 August 1983

Run No. Seas about 4 feet, Speed 16, SEAS Seas about 4 feet

FREQUENCY OF ENCOUNTER (HERTZ)	AMPLITUDE RAO
.015625	1.134166E+03
.023438	1.799643E+02
.031250	3.861227E+02
.035156	3.641217E+02
.039063	8.710075E+02
.046875	2.937183E+02
.058594	1.144229E+03
.066406	1.892432E+02
.074219	3.502111E+02
.078125	1.803117E+02
.082031	4.134755E+01
.117188	1.696074E+01
.156250	1.882731E+00
.195313	5.068444E+00
.234375	1.781120E+01
.273438	1.090349E+01
.312500	3.116931E+00
.351563	5.962380E-01
.390625	9.703673E-02
.429688	3.661502E-01
.468750	4.348732E-01
.507813	4.958833E-01
.546875	9.832310E-02
.585938	1.974270E-01
.625000	1.442297E-01
.664063	3.090819E-01
.703125	1.719991E-01
.742188	4.633045E-02
.781250	6.140242E-02
.820313	2.739386E-02
.859375	2.431101E-02
.898438	2.020627E-02
.937500	7.278029E-02
.976563	1.676112E-01

"WAVAN 2" PROGRAM LISTING

This program calculates and plots Ship Response Amplitude Operations (RAO's). It interfaces with and controls a Hewlett Packard 5420A digital signal analyzer.

```

10  ** WAVAN2 ** 11 AUGUST 1984
20      PROGRAM FOR WAVE ANALYSIS
30      AT USER-ENTERED TAPE SPEED
40      ASSUMES ANALYZER FREQUENCIES
50      CORRESPONDING TO 0-2 Hz REAL TIME
60      PROGRAM OPERATES SPECTRUM ANALYZER
70      ENTER WAVE DATA FIRST
80
90  OPTION BASE 1
100  COM /Plot/ Wxmn,Wxmx,Wymn,Wymx,Vxmn,Vxmx,Vymn,Vymx,Lxmn,Lxmx,Lymn,Lymx,Sf1
q, Gdus,Xvratio
110  COM Y_(0:3,259),X_(2,259),X1,X2,Y1,Y2,Bw,Runtime,Wc,Mc,Csiz
120  DIM Motion$(20)
130  PRINTER IS 1
140  GRAPHICS OFF
150  PRINT CHR$(12)
160  CALL Initcar
170  PRINT "ENTER 1 TO READ NEW DATA THROUGH THE 5420 ANALYZER:"
180  PRINT "ENTER 2 TO PLOT DATA PREVIOUSLY STORED ON DISK."
190  Wv10:Opt=0
200  INPUT "ENTER 1 OR 2",Opt
210  IF Opt=2 THEN Wv90
220  IF Opt=1 THEN Wv10
230  Sa=804
240  Pltr=805
250  INPUT "ENTER ANALYZER SELECT CODE: 804=DEFAULT",Sa
260  INPUT "ENTER PLOTTER SELECT CODE: 805=DEFAULT",Pltr
270  ABORT INT(Sa/100)
280  CLEAR INT(Sa/100)
290  CALL Setup(Motion$,Bw,Runtime,Wc,Mc,Sa)
300  Wv90:CALL Getdata(Motion$,Sa,Pltr,Opt)
310  END
320
330
340  *****
350
360
370  Getdata: SUB Getdata(Motion$,Sa,Pltr,Opt)
380  END
390  OPTION BASE 1
400  COM Y_(0:3,259),X_(2,259),X1,X2,Y1,Y2,Bw,Runtime,Wc,Mc,Csiz
410  DEG
420  INTEGER A(12,2),Index,Flag
430  DIM B(4,2),Maxv_(0:3),Plot_title$(50),Date$(20),Fun$(20),Seas$(20)
440  DIM Cal$(20),Rec(4,259),Rec$(150)
450  Temp_=2
460  Y_(1,259)=Temp_
470  X_(2,259)=Temp_
480  FOR I=1 TO 3
490      Y_(I,259)=0
500  NEXT I
510  IF Opt=1 THEN Gdus
520  Gdus:File$=""
530  INPUT "ENTER FILE NAME",File$
540  ASSIGN @File$ TO File$
550  ENTER @File$:Rec$,Motion$,H+1,B+1,Speed1,Head,Wc,Mc,Rd1,Bw,Rec$,Maxv_
560  ASSIGN @File$ TO *

```

```

570 Speed=Speed1*1.689/32.2
580 Factor=COS(Head)
590 FOR I=1 TO A(3,1)/2
600   r_(0,I)=Rec(2,I)
610   Y_(1,I)=Rec(3,I)
620   Y_(2,I)=Rec(1,I)
630   Y_(3,I)=Rec(4,I)
640   X1=B(2,1)+I*B(3,1)      ! I=1 ???
650   X_(1,I)=X1*(1-X1*6.2832*Speed*Factor)
660   X_(2,I)=B(2,2)+I*B(3,2)  ! I=1 ???2222
670 NEXT I
680 GOTO Opt
690 Gd05:FOR J=1 TO 2
700   IF J=2 THEN Gd10
710   OUTPUT Sa:VAL$(Wc)&".1CA"
720   PRINT "PRESS CONT TO INITIATE WAVE SPECTRUM READ"
730   GOTO Gd20
740 Gd10:OUTPUT Sa:VAL$(Mc)&".1CA"
750   WAIT (400)/1000
760   OUTPUT Sa:"VM"
770   PRINT "PRESS CONT TO INITIATE MOTION SPECTRUM READ"
780 Gd20:PAUSE
790   PRINT FNLine$(1):"PRESS KEY F0 TO END SPECTRUM READ AT ANY TIME"
800   ON KEY 0 GOTO Gd50
810   OUTPUT Sa:"ST"
820 Gd45:GOTO Gd45
830 Gd50:OFF KEY 0
840   OUTPUT Sa:"PA"
850   WAIT (2500)/1000
860   OUTPUT Sa:"401.SA"
870 Getstat:Stat=SPOLL(Sa)
880   IF Stat=96 THEN Getstat
890   FOR I=1 TO 10
900     ENTER Sa:A(I,J)
910   NEXT I
920   FOR I=1 TO 4
930     ENTER Sa:B(I,J)
940   NEXT I
950   FOR I=11 TO 12
960     ENTER Sa:A(I,J)
970   NEXT I
980   FOR I=1 TO A(3,J)/2
990     ENTER Sa:r_(0,I)
1000  NEXT I
1010 NEXT J
1020 Gd60:Rec$=""
1030 INPUT "RECORD DATA (Y or N) ",R$
1040 IF R$="N" THEN Gd80
1050 IF R$="Y" THEN Gd60
1060 Gd65:C$=""
1070 INPUT "CREATE NEW FILE (Y or N) ",X$
1080 IF X$="N" THEN Gd70
1090 IF X$="Y" THEN Gd65
1100 Gd70:File$=""
1110 INPUT "ENTER FILE NAME",File$
1120 IF X$="Y" THEN CREATE BOMF File$,1,9000

```

```

1130 ASSIGN @File1 TO File$
1140 Rec$=""
1150 INPUT "ENTER FILE INFO HEADING (160 CHAR MAX)",Rec$
1160 Gd80:FOR I=1 TO 3
1170   Maxv_(I)=0
1180 NEXT I
1190 FOR I=1 TO 2
1200   B(2,I)=B(2,I)/Bw
1210   B(3,I)=B(3,I)/Bw
1220 NEXT I
1230 INPUT "Ship speed in kts",Speed1
1240 Speed=Speed1*1.689/32.2
1250 INPUT "Heading 180=Head Seas",Head
1260 Factor=COS(Head)
1270 Flag=0
1280 FOR I=1 TO A(3,1)/2      ' 0-2 Hz
1290   X1=B(2,1)+I*B(3,1)      ' I=1 0000000
1300   X_(1,I)=X1*(1-X1*6.2832*Speed*Factor)
1310   Temp_y_(1,I)*Bw
1320   Rec(2,I)=Temp_
1330   Y_(0,I)=Temp_
1340   Y_(1,I)=Temp_/ (1-12.5664*X1*Speed*Factor)
1350   Rec(3,I)=Y_(1,I)
1360   IF X1<.05 THEN Next1
1370   Diff=Y_(1,I)-Y_(1,I-1)
1380   IF (Diff<0) AND (Flag=0) THEN Next1
1390   Flag=1
1400   IF Y_(1,I)>Maxv_(1) THEN Maxv_(1)=Y_(1,I)
1410 Next1:NEXT I
1420 X2=X_(1,A(3,1)/2)
1430 Flag=0
1440 FOR I=1 TO A(3,2)/2      ' 0-2 Hz
1450   X_(2,I)=B(2,2)+I*B(3,2)      ' I=1 0000000
1460   Temp_=Bw*Y_(2,I)
1470   IF Motion$="HEAVE" THEN Y_(2,I)=Temp_
1480   IF Motion$="HEAVE" THEN Y_(2,I)=Temp_/ (2*PI*X_(2,I))
1490   Rec(1,I)=Y_(2,I)
1500   IF X_(2,I)<.05 THEN Next
1510   Diff=Y_(2,I)-Y_(2,I-1)
1520   IF (Diff<0) AND (Flag=0) THEN Next
1530   Flag=1
1540   IF Y_(2,I)>Maxv_(2) THEN Maxv_(2)=Y_(2,I)
1550 Next:NEXT I
1560 I1=0
1570 Flag=0
1580 FOR I=1 TO A(3,2)/2      ' 0-2 Hz
1590 Next1:IF X_(1,I1+1)*X_(2,I) THEN Cont
1600   I1=I1+1
1610   GOTO Next1
1620 Cont:IF I1=0 THEN Next2
1630   Gd2=(Y_(1,I1+1)+Y_(1,I1)+X_(2,I)-X_(1,I1))
1640   Gd1=Gd2*(X_(1,I1+1)-X_(1,I1))+X_(1,I1)
1650   IF Gd1=0 THEN Gd1=.1E-5

```

```

1660 Temp=Y_(3,I)/Dd1
1670 Rec(4,I)=Temp_
1680 Y_(3,I)=Temp_
1690 IF I=258 THEN Y_(3,I)=0
1700 IF X_(2,I)<.05 THEN Nxt12
1710 Diff=Y_(3,I)-Y_(3,I-1)
1720 IF (Diff=0) AND (Flag=0) THEN Nxt12
1730 Flag=1
1740 IF Y_(3,I) > Maxy_(3) THEN Maxy_(3)=Y_(3,I)
1750 Nxt12:NEXT I
1760 Flag=0
1770 FOR I=1 TO A(3,2)/2
1780 IF X_(2,I)<.05 THEN Gd90
1790 D=Y_(0,I)-Y_(0,I-1)
1800 IF (D=0) AND Flag=0 THEN Gd90
1810 Flag=1
1820 IF Y_(0,I) > Maxy_(0) THEN Maxy_(0)=Y_(0,I)
1830 Gd90:NEXT I
1840 IF R$="Y" THEN OUTPUT @File1:Rec$,Motion$,A(*),B(*),Speed1,Head,Wc,Mc,Dd1
1850 IF R$="Y" THEN ASSIGN @File1 TO *
1860 Opt: PRINT FNLine(2):"ENTER 1 TO PLOT DATA:"
1870 PRINT "ENTER 2 FOR TABULAR PRINTOUT"
1880 Opt10: Opt=0
1890 Popt=0
1900 INPUT "ENTER 1 OR 2",Opt
1910 IF Opt=1 THEN Gd
1920 IF Opt=2 THEN Opt10
1930 PRINT FNLine(1):"PRINT OPTIONS: MOTION=1,WAVE=2,RAO=7,RAW WAVE SPECTRUM=4"
1940 Opt20: Popt=0
1950 INPUT "ENTER PRINT OPTION CODE (1-4)",Popt
1960 IF Popt=1 OR Popt=4 THEN Opt20
1970 Gd:CALL Grid:Popt,Motion$,Maxy_(*),Speed1,Fltr,Plot_title$,Date$,Run$,Seas
$,CalF,Index)
1980 CALL Plotdata:Popt,A(7,2)/2,Index) " 0-2 Hz
1990 INPUT "Make another plot or printout with this data (Y or N)",C$
2000 IF C$(1,1)="N" THEN Gd90
2010 GOTO Opt
2020 Gd90:FEN 0
2021 GRAPHICS OFF
2022 PRINT CHR$(12)
2030 SUBEND
2040
2050
2060 *****
2070
2080
2090 SUB Plotdata:Popt,Numpoints,INTEGER Index:
2100 OPTION BASE 1
2110 DIM X(1:258),Y(1:258),X1,X2,X1,X2,Ww,RunTime,Wc,Mc,Isis
2120 IF Popt THEN Gd90

```

```

2130 VIEWPORT 22,170,45,242
2140 CALL Locate(18,98,25,115)
2150 WINDOW (X1),(X2),(Y1),(Y2)
2160 MOVE 0,0
2170 Pd03: Ind1=2
2180 IF Index=1 THEN Ind1=1
2190 Di+1=Y_(Index,I)
2200 I1=1
2210 FOR I=2 TO Numpoints
2220 IF Popt THEN Pd04
2230 Di=Dif1
2240 Dif1=Y_(Index,I)-Y_(Index,I-1)
2250 IF SGN(Dif1)≠SGN(Dif1) THEN Pd05
2260 IF (ABS((Y_(Index,I-1)-Y_(Index,I1))/Y2)≤.05) AND (Y_(Index,I-1)≤.1*Y
2) THEN Pd05
2270 Pd04: PRINT USING For: X_(Ind1,I-1),Y_(Index,I-1)
2280 IF Popt THEN Pd15
2290 I1=I-1
2300 GOTO Pd10
2310 Pd05: IF (I-1) MOD 10=0 THEN PRINT USING For: X_(Ind1,I-1),Y_(Index,I-1)
2320 Pd10: IF X_(Ind1,I)≠.05 THEN DRAW X_(Ind1,I),Y_(Index,I)
2340 Pd15: NEXT I
2350 For: IMAGE 14X,MOD,DDDDDD,20X,MD,DDDDDDDE
2360 IF Popt=0 THEN CALL Power(Numpoints,X2,Y2,Index)
2370 SUBEND
2380
2390
2400 *****
2410
2420
2430 Grid: SUB Grid(Popt,Motion$,rmax(*),Speed1,Pltr,Plot_title$,Date$,Run$,Seas$,
,Cal$,INTEGER Index)
2440 OPTION BASE 1
2450 DIM Y_ (0:3,259),X_ (2,259),Xmin,Maxx,Ymin,Maxy,Bw,Runtime,Wc,Mc,Csiz
2460 INTEGER Botlin
2470 Botlin=Popt
2480 IF Popt THEN Gd10
2490 GINIT
2500 Pl: Pl=0
2510 INPUT "PRESS CONT TO PLOT ON CRT; ENTER 1 TO PLOT ON PLOTTER",P1
2520 IF P1=0 AND P1=1 THEN P1
2530 IF P1 THEN PLOTTER IS (INT(Pltr/100)*100+Pltr MOD 100,"HFGL"
2540 IF P1 THEN PLOTTER IS 805,"HFGL"
2550 IF P1=0 THEN PLOTTER IS 3,"INTERNAL"
2560 Pldev=Pltr*P1+0*NOT P1
2570 IF P1 THEN INPUT "Put paper on plotter, PUSH CONT",A
2580 IF P1=0 THEN VIEWPORT 20,120,20,37
2590 IF P1=0 THEN GRAPHICS ON
2600 IF P1 THEN VIEWPORT 10,80,20,30
2610 Csize=0
2620 IF P1 THEN Csize=1
2630 WINDOW 18,98,25,115
2640 PEN 1
2650 FRAME
2660 CLIP 17,79,24,115

```

```

2570 Temp = 0
2580 Xmin = Temp
2590 Ymin = Temp
2700 Renter: PRINT "PLOT TYPE CODES: "; Motion$; " = 1: " WAVE = 2 " Motion$; " RAD = 3 RA
W WAVE = 4"
2710 INPUT "ENTER PLOT TYPE CODE (1-4)", Botlin
2720 IF (Botlin = 1) OR (Botlin = 4) THEN Renter
2730 Gd10: ON Botlin GOTO Motion, Wave, Rad, Rawwave
2740
2750
2760 *****
2770
2780
2790 Size: ' SUBROUTINE TO DETERMINE ORDINATE SIZE
2800
2810 I = 1
2820 Check size: IF (Maxv = 1) AND (Maxv < 100) THEN Done
2830 IF Maxv < 1 THEN TooBig
2840 I = I * 10
2850 Maxv = Maxv * 10
2860 GOTO Check_size
2870 TooBig: I = I * 10
2880 Maxv = Maxv * 10
2890 GOTO Check_size
2900 Done: Maxv = INT(Maxv) * I
2910 IF Maxv < (maxIndex) THEN Connect
2920 Loopv: Maxv = Maxv + I * 10
2930 IF Maxv < (maxIndex) THEN Loopv
2940 Connect: RUSUB Intstep
2950 RETURN
2960
2970
2980 *****
2990
3000
3010 Intstep: ' SUBROUTINE Intstep
3020
3030 I = 1
3040 Step = Maxv / 10
3050 IF (INT Step = 0) THEN Stopm
3060 Loop1: IF I = 1 THEN
3070 Step = Step * I
3080 IF (INT Step = 0) THEN Loop1
3090 Stopm: IF (INT Step = 0) THEN Loop1
3100 Loop1: I = I * 10
3110 Step = Step * I
3120 IF (INT Step = 0) THEN Loop1
3130 Stop: Step = INT Step
3140 IF (Step = 1) THEN Step = 1 IF (Step = 1) THEN
3150 IF (Step = 1) THEN Step = 1
3160 IF (Step = 1) THEN Step = 1 IF (Step = 1) THEN Step = 1
3170 IF (Step = 1) THEN Step = 1

```

AD-A157 552

COMPARATIVE CHARACTERISTICS OF UNITED STATES COAST
GUARD 95' AND 82' CLAS. (U) COAST GUARD RESEARCH AND
DEVELOPMENT CENTER GROTON CT T J COE ET AL. APR 85
USCG-D-21-85 F/G 13/1

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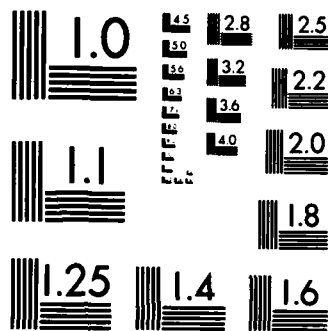
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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3180 Ok:Stepunit=Step
3190 Step=Step*I
3200 RETURN
3210 !
3220 !
3230 ! *****
3240 !
3250 !
3260 Motion:L$=Motion$
3270 Index=2
3280 GOTO Setup
3290 Wave:L$="WAVE"
3300 Index=1
3310 IF Popt THEN Setup
3320 Maxy=ymax(1)*1.05
3330 GOSUB Size
3340 Maxx=INT(Maxx*1.1)
3350 IF Maxx<1 THEN Maxx=1
3360 WINDOW 0,(Maxx),0,(Maxy)
3370 IF Maxx<=2 THEN AXES .1,Step
3380 IF Maxx>2 THEN AXES .5,Step
3390 GOTO Setup50
3400 Rrao:L$=Motion$&" RAO"
3410 Index=3
3420 GOTO Setup
3430 Rawwave: L$="RAW WAVE SPECTRUM"
3440 Index=0
3450 Setup: IF Popt=0 THEN Setup20
3460 PRINT FNLin$(3); " FREQUENCY
";L$;FNLin$(1)
3470 SUBEXIT
3480 Setup20:Maxy=ymax(Index)*1.05
3490 GOSUB Size
3500 WINDOW 0,1,0,(Maxy)
3510 AXES .1,Step
3520 CLIP OFF
3530 Maxx=1
3540 Setup50:CALL Label_ticks(Maxx,Maxy,Stepunit,Step,Csiz)
3550 CALL Label_axes(L$,Pltdev,Maxx,Maxy,Csiz)
3560 CALL Title(Motion$,Plot_title$,Date$,Maxx,Maxy,Botlin,Csiz)
3570 CALL Info(Speed1,Run$,Seas$,Cal$,Maxx,Maxy,Csiz,Index)
3580 SUBEND
3590 !
3600 !
3610 ! *****
3620 !
3630 !
3640 SUB Label_ticks(Maxx,Maxy,Unit,Step,Csiz)
3650 DIM X$(50),Y$(30)
3660 Y=-Maxy*.024
3670 CSIZE Csiz*.5
3680 LOGO o

```

```

3690 LDIR 0
3700 Num_ticks=INT(Maxx*10)
3710 IF Num_ticks>=20 THEN Lt10
3720 CLIP OFF
3730 FOR J=0 TO Num_ticks
3740     MOVE J/10/Maxx,Y
3750     LABEL USING "K";J/10
3760 NEXT J
3770 GOTO Lt15
3780 Lt10:FOR J=0 TO Num_ticks
3790     MOVE J/10/Maxx,Y
3800     IF J MOD 10=0 THEN LABEL USING "K";J/10
3810 NEXT J
3820 Lt15:LORG 8
3830 X=-Maxx*.024
3840 Num_ticks=INT(Maxv/Step)
3850 IF Unit=5 THEN Step5
3860 Num_labels=Num_ticks DIV 5
3870 Step=Step*5
3880 GOTO Cont
3890 Step5:Num_labels=Num_ticks DIV 2
3900 Step=Step*2
3910 Cont:IF Step<=.001 THEN Lt20
3920 FOR J=0 TO Num_labels
3930     MOVE X,Step*J
3940     LABEL USING "K";Step*J
3950 NEXT J
3960 GOTO Lt30
3970 Lt20:DEG
3980 LORG 4
3990 CSIZE Csize..35
4000 LDIR 90
4010 FOR J=0 TO Num_labels
4020     MOVE X,Step*J
4030     LABEL USING "D.DE";Step*J
4040 NEXT J
4050 Lt30:SUBEND
4060 !
4070 !
4080 ! *****
4090 !
4100 !
4110 SUB Label_axes(A$,Pitr,Maxx,Maxv,Csize)
4120 OPTION BASE 1
4130 DIM L$(40)
4140 DEG
4150 LDIR 0
4160 CSIZE Csize
4170 LORG 5
4180 MOVE Maxx/2,-Maxv*.05
4190 IF A$="RAW WAVE SPECTRUM" THEN
4200 LABEL USING "K";"FREQUENCY (Hz)"
4210 ELSE

```

```

4230 LABEL USING "K";"FREQUENCY OF ENCOUNTER (Hz)"
4240 END IF
4250 MOVE -Maxx*.15,Maxy/2.5
4260 CSIZE Csize,.5
4270 LDIR 90
4280 IF A$<>"RAW WAVE SPECTRUM" THEN Notraw
4290 CALL Splab("Ft"&CHR$(169)&"-sec")
4300 L$="WAVE POWER SPECTRAL DENSITY"
4310 GOTO Xlab
4320 Notraw: IF A$<>"ROLL" THEN Notroll
4330 CALL Splab("Deg"&CHR$(169)&"-sec")
4340 L$="ROLL ENERGY SPECTRUM"
4350 GOTO Xlab
4360 Notroll: IF A$<>"WAVE" THEN Notwave
4380 CALL Splab("Deg"&CHR$(169)&"-sec")
4390 L$="WAVE ENERGY SPECTRUM"
4400 GOTO Xlab
4410 Notwave: IF A$<>"ROLL RAO" THEN Notrao
4510 CALL Splab("Y"&CHR$(168)&CHR$(170)&"(f) = ("&CHR$(168)&"/"&CHR$(170)&)" "&CHR$(169))
4520 L$="ROLL RESPONSE AMPLITUDE OPERATOR"
4530 GOTO Xlab
4540 Notrao: IF A$<>"PITCH" THEN Notpitch
4550 CALL Splab("Deg"&CHR$(169)&"-sec")
4600 L$="PITCH ENERGY SPECTRUM"
4610 GOTO Xlab
4620 Notpitch: IF A$<>"PITCH RAO" THEN Notprao
4630 CALL Splab("Y"&CHR$(171)&CHR$(170)&"(f) = (")
4640 CSIZE Csize+1,.5
4650 CALL Splab(CHR$(171))
4660 CSIZE Csize,.5
4670 CALL Splab("/"&CHR$(170)&)" "&CHR$(169))
4720 L$="PITCH RESPONSE AMPLITUDE OPERATOR"
4730 GOTO Xlab
4740 Notprao: IF A$<>"HEAVE" THEN Nothev
4750 CALL Splab("Ft"&CHR$(169)&"-sec")
4800 L$="HEAVE ENERGY SPECTRUM"
4810 GOTO Xlab
4820 Nothev: CALL Splab("Y"&CHR$(172)&CHR$(170)&"(f) = (Z/"&CHR$(170)&)" "&CHR$(169))
4890 L$="HEAVE RESPONSE AMPLITUDE OPERATOR"
4900 Xlab: MOVE Maxx/2,-Maxy*.1
4910 LORG 6
4920 LDIR 0
4930 CSIZE Csize+1,.6
4940 LABEL USING "K";L$
4950 SUBEND
4960 !
4970 !
4980 ! *****
4990 !
5000 !
5010 Title: SUB Title(Motion$,Plot_titles$,Date$,Maxx,Maxy,INTEGER Code,REAL Csize)

```

```

5020 PRINTER IS 1
5030 PRINT FNLin$(5)
5040 LDIR 0
5050 CSIZE Csize+1,.6
5060 LORG 4
5070 MOVE Maxx/2,Maxy*1.1
5080 INPUT "ENTER PLOT TITLE [60 CHAR MAX]",Plot_titles$
5090 LABEL USING "k";Plot_titles$
5100 PRINT TAB(20),Plot_titles$;FNLin$(1)
5110 MOVE Maxx/2,Maxy*1.04
5120 CSIZE Csize,.6
5130 INPUT "DATE",Date$
5140 LABEL USING "k";"Tested "&Date$
5150 CLIP ON
5160 ON Code GOTO C1,C2,C3,C4
5170 C1:PRINT TAB(20),Motion$&" Energy Spectrum"
5180 GOTO Cend
5190 C2:PRINT TAB(20),"Wave Energy Spectrum"
5200 GOTO Cend
5210 C3:PRINT TAB(13),Motion$&" Response Amplitude Operator"
5220 GOTO Cend
5230 C4:PRINT TAB(17),"Wave Power Spectral Density"
5240 Cend:PRINT TAB(23),"Tested "&Date$
5250 SUBEND
5260 !
5270 !
5280 ! *****
5290 !
5300 !
5310 SUB Info(S,Runs$,Seas$,Cal$,Maxx,Maxy,Csize,INTEGER Index)
5320 LDIR 0
5330 CSIZE Csize,.5
5340 LORG 2
5350 MOVE .6*Maxx,.95*Maxy
5360 INPUT "Run no.",Run$
5370 LABEL USING Run;Run$
5380 Run:IMAGE "Run No. ",3A
5390 PRINT FNLin$(1); " Run No. ":Run$;
5400 IF Index=0 THEN Nosea
5410 INPUT "SEAS",Seas$
5420 LABEL USING "20A";Seas$
5430 PRINT ". Speed ":S;" SEAS ":Seas$;FNLin$(1)
5440 Nosea: PRINT " FREQUENCY OF ENCOUNTER AMPLITUDE"
5450 LABEL USING Speed:S
5460 Speed:IMAGE "Speed ",DD.D." kts"
5470 INPUT "CALIBRATION",Cal$
5480 IF Cal$="0" THEN SUBEXIT
5490 LABEL USING Cal;Cal$
5500 Cal:IMAGE "Calibration ",7A
5510 SUBEND
5520 !
5530 !
5540 ! *****

```

```

5550 !
5560 !
5570 Power:SUB Power(Numpoints,Maxx,Maxy,INTEGER Index)
5580 OPTION BASE 1
5590 COM Y_(0:3,259),X_(2,259),X1,X2,Y1,Y2,Bw,Runtime,Wc,Mc,Csiz
5600 IF (Index=2) OR (Index=3) THEN SUBEXIT
5610 Ind1=1
5620 IF Index=0 THEN Ind1=2
5630 Sum=0
5640 FOR I=1 TO Numpoints
5650 IF X_(Ind1,I)<.03 THEN NextI
5660 Sum=Sum+Y_(Index,I)*(X_(Ind1,I+1)-X_(Ind1,I))
5670 NextI:NEXT I
5680 CSIZE Csiz, .5
5690 LONG 2
5700 LDIR 0
5710 MOVE Maxx/2,Maxy*.7
5740 CALL Splab("Power (ft) "&CHR$(169)&"=")
5741 LABEL USING "DDD.DDD";Sum
5750 IF Index=1 THEN SUBEXIT
5760 MOVE Maxx/2,.55*Maxy
5770 LABEL USING "K";"Significant Wave Height"
5771 MOVE .55*Maxx,.50*Maxy
5772 CALL Splab("(H 1/3) = 4"&CHR$(173)&"Power")
5780 MOVE .55*Maxx,.45*Maxy
5790 LABEL USING "K,2D.2D,K";"(H 1/3)=",4*SQR(Sum)," ft"
5800 SUBEXIT
5810 STOP
5820 ! -----
5830 SUBEND
5840 Setup:SUB Setup(Motion$,Bw,Runtime,Wc,Mc,Sa)
5850 OPTION BASE 1
5860 DIM S$(100),Wdth(7)
5870 Wdth(1)=.9375
5880 Wdth(2)=1.875
5890 Wdth(3)=3.75
5900 Wdth(4)=7.5
5910 Wdth(5)=15
5920 Wdth(6)=30
5930 Wdth(7)=60
5940 INPUT "TURN 5420 SYSTEM ON - PRESS CONT",X
5950 PRINT FNLine$(1):"TAPE SPEED OPTION CODES:"
5960 PRINT " 1) 15/16 ips"
5970 PRINT " 2) 1 7/8 ips"
5980 PRINT " 3) 3 3/4 ips"
5990 PRINT " 4) 7 1/2 ips"
6000 PRINT " 5) 15 ips"
6010 PRINT " 6) 30 ips"
6020 PRINT " 7) 60 ips"
6030 Set10:Uts=0
6040 PRINT FNLine$(1):"ENTER ORIGINAL RECORDING TAPE SPEED CODE (1-7)"
6050 INPUT "ENTER RECORD SPEED CODE (1-7)",Uts

```

```

6060 IF (Ots<1) OR (Ots>7) THEN Set10
6070 Set15:Pts=0
6080 PRINT FNLin$(1):"ENTER PLAYBACK TAPE SPEED CODE (1-7)"
6090 INPUT "ENTER PLAYBACK SPEED CODE (1-7)",Pts
6100 IF (Pts<1) OR (Pts>7) THEN Set15
6110 Bw=Wdth(Pts)/Wdth(Ots)
6120 !
6130 Set20:Wc=0
6140 INPUT "ENTER WAVE SPECTRUM CALIBRATION FACTOR",Wc
6150 IF Wc<=0 THEN Set20
6160 !
6170 Set25:Motion$=""
6180 INPUT "ENTER TYPE OF MOTION (ROLL, PITCH OR HEAVE)",Motion$
6190 IF Motion$<>"ROLL" AND Motion$<>"PITCH" AND Motion$<>"HEAVE" THEN Set25
6200 !
6210 Set30:Mc=0
6220 INPUT "ENTER MOTION SPECTRUM CALIBRATION FACTOR",Mc
6230 IF Mc<=0 THEN Set30
6240 !
6250 Set40: X$=""
6260 ! INPUT "RUN WITH REAL-TIME CLOCK (Y or N)?",X$
6270 ! IF X$="N" THEN Set60
6280 ! IF X$<>"Y" THEN Set40
6290 !
6300 Set50:Runtime=0
6310 ! INPUT "ENTER MAXIMUM RUNTIME (MINUTES)",Runtime
6320 ! IF Runtime<=0 THEN Set50
6330 !
6340 Set60: !
6350 PRINT "PRESS CONT TO INITIATE ANALYZER SELF-TEST"
6360 PAUSE
6370 S$="1CH 1RG 1AC 2SB 1TG 1000,1AV OCF "&VAL$(Bw)&"BW "
6380 Set80:X=POS(S$," ")
6390 OUTPUT Sa:S$(1,X)
6400 IF X=LEN(S$) THEN Set90
6410 S$=S$(X+1)
6420 WAIT (400)/1000
6430 GOTO Set80
6440 Set90:SUBEND
6450 !
LIBRARY SUB's ADDED BY THE TRANSLATOR

6460 DEF FNLin$(INTEGER X) ! LIN function of PRINT
6470 INTEGER I
6480 IF X=0 THEN RETURN CHR$(13)
6490 ALLOCATE R$(ABS(X)+1)
6500 R$=CHR$(13)
6510 IF X<0 THEN R$=""
6520 FOR I=1 TO ABS(X)
6530 R$=R$&CHR$(10)
6540 NEXT I
6550 RETURN R$
6560 FNEND

```

```

6570 !
6580 !
6590 ! *****
6600 New_udc: SUB New_udc(Char$,Array(*))
6610 ! This allows up to twenty new characters to be defined, each having up
6620 ! to thirty elements (rows in the array) for definition.
6630 OPTION BASE 1
6640 COM /Udc/ Old_chars$(20),Size(20),Chars(20,30,3)
6650 IF LEN(Old_chars$)=20 THEN
6660 PRINT "User-defined Character table full."
6670 ELSE ! (still room)
6680 Pos=LEN(Old_chars$)+1
6690 Old_chars$(Pos)=Char$
6700 Size(Pos)=SIZE(Array,1)
6710 FOR Row=1 TO Size(Pos)
6720 FOR Column=1 TO 3
6730 Chars(Pos,Row,Column)=Array(Row,Column)
6740 NEXT Column
6750 NEXT Row
6760 END IF ! (room left?)
6770 SUBEND
6780 ! *****
6790 Splab: SUB Splab(Text$)
6800 ! This prints a character string at the current pen position and using
6810 ! the current LORG, LDIR and CSIZE. The LORG will need to be redeclared
6820 ! upon returning to the calling context, as this routine needs LORG 1 if
6830 ! the text is longer than one character.
6840 OPTION BASE 1
6850 COM /Udc/ Old_chars$(20),Size(20),Chars(20,30,3)
6860 REAL Array(31,3)
6870 FOR Char=1 TO LEN(Text$)
6880 IF Char=2 THEN LORG 1 ! Necessary when doing one character at a time
6890 Char$=Text$(Char;1)
6900 Pos=POS(Old_chars$,Char$) ! Is this to be replaced by a UDC?
6910 IF Pos THEN
6920 REDIM Array(Size(Pos),3)
6930 FOR Row=1 TO Size(Pos)
6940 FOR Column=1 TO 3
6950 Array(Row,Column)=Chars(Pos,Row,Column) ! \ Take a slice out
6960 NEXT Column ! > of the 3D array
6970 NEXT Row ! / and put it in the
6980 WHERE X,Y ! / 2D array for
6990 SYMBOL Array(*) ! / SYMBOL.
7000 MOVE X,Y
7010 LABEL USING "#,K";" " ! Tell the computer to update the pen position
7020 ELSE ! (regular character)
7030 LABEL USING "#,K";Char$
7040 END IF ! (this character been redefined?)
7050 NEXT Char
7060 SUBEND
7061 !
7062 !
7070 Initcar: SUB Initcar
7071 OPTION BASE 1

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7073 DIM Sy1(11,3),Sy2(6,3),Sy3(13,3),Sy4(12,3),Sy5(6,3),Sy6(5,3)
7074 COM /Udc/ Old_chars$(20),Size(20),Chars(20,30,3)
7080 READ Sy1(*),Sy2(*),Sy3(*),Sy4(*),Sy5(*),Sy6(*)
7090 DATA 0,7,-1, 1,9,-1, 3,9,-1, 4,7,-1, 4,4,-1, 3,2,-1, 1,2,-1, 0,4,-1, 1,9
,2, 1,-1,-1, 3,12,-1 ! PHI
7100 DATA 2,8,-2, 0,8,-1, 2,12,-1, 2,14,-1, 1,15,-1, 0,14,-1 ! SQUARED
7110 DATA 0,0,-2, 1,0,-1, 3,2,-1, 3,3,-1, 2,5,-1, 1,5,-1, 0,6,-1, 0,10,-1, 1,1
1,-1, 2,11,-1, 3,10,-1, 2,9,-1, 1,11,-1, 1,12,-1 ! ZETA
7120 DATA 0,5,-2, 0,7,-1, 1,9,-1, 2,9,-1, 3,7,-1, 3,3,-1, 2,1,-1, 1,1,-1, 0,5,
-1, 0,5,-1, 3,5,-1 ! THETA
7130 DATA 0,5,-2, 3,5,-1, 0,-3,-1, 3,-3,-1, 1,1,-2, 2,1,-1 ! EUROPEAN Z
7131 DATA 1,7,1, 2,7,-1, 3,4,-1, 3,14,-1, 54,14,-1 ! SQRT
7140 Old_chars$=""
7150 New_udc(CHR$(168),Sy1(*)) ! PHI
7160 New_udc(CHR$(169),Sy2(*)) ! SQUARED
7170 New_udc(CHR$(170),Sy3(*)) ! ZETA
7180 New_udc(CHR$(171),Sy4(*)) ! THETA
7190 New_udc(CHR$(172),Sy5(*)) ! Z
7191 New_udc(CHR$(173),Sy6(*)) ! SQUARE ROOT
7200 SUBEND

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END

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